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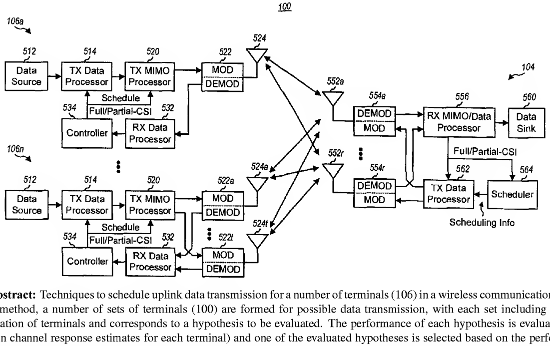

(57) Abstract: Techniques to schedule uplink data transmission for a number of terminals (106) in a wireless communication system. In one method, a number of sets of terminals (100) are formed for possible data transmission, with each set including a unique combination of terminals and corresponds to a hypothesis to be evaluated. The performance of each hypothesis is evaluated (e.g., based on channel response estimates for each terminal) and one of the evaluated hypotheses is selected based on the performance. The terminals in the selected hypothesis are scheduled for data transmission. A successive cancellation receiver processing scheme may be used to process the signals transmitted by the scheduled terminals. In this case, one or more orderings of the terminals in each set may be formed, with each terminal ordering corresponding to a sub-hypothesis to be evaluated. The performance of each sub-hypothesis is then evaluated and one of the sub-hypotheses is selected.

WO 02/093782 A1

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ALLOCATION OF UPLINK RESOURCES IN A MULTI-INPUT MULTI-OUTPUT (MIMO) COMMUNICATION SYSTEM

BACKGROUND

Field

[1001] The present invention relates generally to data communication, and more specifically to techniques for allocating uplink resources in a multiple-input multiple-output (MIMO) communication system, which may advantageously utilize channel state information (CSI) and may further employ successive cancellation (SC) receiver processing to provide improved system performance.

Background

[1002] Wireless communication systems are widely deployed to provide various types of communication such as voice, data, and so on, for a number of users. These systems may be based on code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), or some other multiple access techniques.

[1003] A multiple-input multiple-output (MIMO) communication system employs multiple (N_T) transmit antennas and multiple (N_R) receive antennas for data transmission. In one common MIMO system implementation, the N_T transmit antennas are located at and associated with a single transmitter system, and the N_R receive antennas are similarly located at and associated with a single receiver system. A MIMO system may also be effectively formed for a multiple access communication system having a base station that concurrently communicates with a number of terminals. In this case, the base station employs a number of antennas and each terminal may employ one or more antennas.

[1004] A MIMO channel formed by the N_T transmit and N_R receive antennas may be decomposed into N_C independent channels, with $N_C \leq \min\{N_T, N_R\}$. Each of the N_C independent channels is also referred to as a spatial subchannel of the MIMO channel and corresponds to a dimension. The MIMO system can provide improved performance

(e.g., increased transmission capacity) if the additional dimensionalities created by the multiple transmit and receive antennas are utilized.

[1005] The available resources for uplink transmissions from the terminals to the base station are limited. Typically, only a fraction of the terminals may be scheduled for transmission on the available spatial subchannels, which may be limited by the number of antennas employed at the base station. Each "possible" spatial subchannel between a terminal and the base station typically experiences different link characteristics and is associated with different transmission capability. Efficient use of the available uplink resources (e.g., higher throughput) may be achieved if the available spatial subchannels are effectively allocated such that data is transmitted on these subchannels by a "proper" set of terminals in the MIMO system.

[1006] There is therefore a need in the art for techniques to allocate uplink resources in a MIMO system to provide improved system performance.

SUMMARY

[1007] Aspects of the invention provide techniques to increase the uplink performance of a wireless communication system. In an aspect, scheduling schemes are provided to schedule data transmissions from terminals that employ single antenna (i.e., SIMO terminals) and/or terminals that employ multiple antennas (i.e., MIMO terminals). By allowing multiple data transmissions to occur simultaneously (e.g., on the same frequency band) from multiple SIMO terminals, one or more MIMO terminals, or a combination thereof, the capacity of the system is increased relative to that achieved when only one terminal is allowed to transmit in a given time interval, as is typically performed in conventional time-division multiplexed (TDM) systems. The scheduling schemes are described in further detail below.

[1008] In another aspect, MIMO receiver processing techniques are used at the base station to increase system capacity. With MIMO, scheduled terminals transmit multiple independent data streams from a number of transmit antennas. If the propagation environment has sufficient scattering, the MIMO receiver processing techniques efficiently exploit the spatial dimensionality of the MIMO channel to support increased data rates for the terminals. At the MIMO receiver (i.e., the base station for the uplink), multiple receive antennas are used in conjunction with array signal processing

techniques (described below) to recover the transmitted data streams from one or more terminals.

[1009] A specific embodiment of the invention provides a method for scheduling uplink data transmission for a number of terminals in a wireless communication system. In accordance with the method, a number of sets of terminals are formed for possible data transmission, with each set including a unique combination of terminals and corresponds to a hypothesis to be evaluated. The performance of each hypothesis is evaluated and one of the evaluated hypotheses is selected based on the performance. The hypotheses may be evaluated based in part on channel response estimates for each terminal in the hypothesis, with the channel response estimates being indicative of channel characteristics between the terminal and a base station. The terminals in the selected hypothesis are scheduled for data transmission.

[1010] A successive cancellation receiver processing scheme may be used to process the signals transmitted by the scheduled terminals. In this case, one or more orderings of the terminals in each set may be formed, with each terminal ordering corresponding to a sub-hypothesis to be evaluated. The performance of each sub-hypothesis is then evaluated and one of the sub-hypotheses is selected.

[1011] Each transmit antenna of each scheduled terminal may transmit an independent data stream. To achieve high performance, each data stream may be coded and modulated based on a scheme selected, for example, based on a signal-to-noise-plus-interference (SNR) estimate for the antenna used to transmit the data stream.

[1012] Terminals desiring data transmission (i.e., "active" terminals) may be prioritized based on various metrics and factors. The priority of the active terminals may then be used to select which terminal(s) to be considered for scheduling and/or to assign the available transmission channels and processing order to the selected terminals.

[1013] The invention further provides methods, systems, and apparatus that implement various aspects, embodiments, and features of the invention, as described in further detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

[1014] The features, nature, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

[1015] FIG. 1 is a diagram of a multiple-input multiple-output (MIMO) communication system that may be designed and operated to implement various aspects and embodiments of the invention;

[1016] FIG. 2 is a flow diagram of a process to schedule terminals for transmission, in accordance with an embodiment of the invention;

[1017] FIGS. 3A and 3B are flow diagrams for two successive cancellation (SC) receiver processing schemes whereby the processing order is (1) imposed by an ordered set of terminals and (2) determined based on the post-processed SNRs, respectively;

[1018] FIG. 4 is a flow diagram for a priority-based scheduling scheme whereby the highest priority terminals are considered for scheduling;

[1019]

[1020] FIG. 5 is a simplified block diagram of a number of terminals and a base station in the MIMO system shown in FIG. 1;

[1021] FIG. 6 is a block diagram of an embodiment of the transmit portion of a terminal capable of processing data for transmission to the base station based on the available CSI;

[1022] FIG. 7 is a block diagram of an embodiment of the receive portion of a base station;

[1023] FIGS. 8A and 8B are block diagrams of an embodiment of a channel MIMO/data processor and an interference canceller, respectively, of a receive (RX) MIMO/data processor at the base station; and

[1024] FIGS. 9A and 9B show the average throughput and the sensitivity in cell throughput, respectively, for a simulated network.

DETAILED DESCRIPTION

[1025] FIG. 1 is a diagram of a multiple-input multiple-output (MIMO) communication system 100 that may be designed and operated to implement various

aspects and embodiments of the invention. MIMO system 100 employs multiple (N_T) transmit antennas and multiple (N_R) receive antennas for data transmission. MIMO system 100 is effectively formed for a multiple access communication system having a base station (BS) 104 that concurrently communicates with a number of terminals (T) 106. In this case, base station 104 employs multiple antennas and represents the multiple-output (MO) for uplink transmissions and the multiple-input (MI) for downlink transmissions. The set of "communicating" terminals 106 collectively represents the multiple-input for uplink transmissions and the multiple-output for the downlink transmissions. A communicating terminal is one that transmits user-specific data to or receives user-specific data from the base station. If each communicating terminal 106 employs one antenna, then that antenna represents one of the N_T transmit antennas if the terminal is transmitting data and one of the N_R receive antennas if the terminal is receiving data. A terminal may also employ multiple antennas (not shown in FIG. 1 for simplicity), and these antennas may advantageously be used for data transmission.

[1026] MIMO system 100 may be operated to transmit data via a number of transmission channels. A MIMO channel may be decomposed into N_C independent channels, with $N_C \leq \min \{N_T, N_R\}$. Each of the N_C independent channels is also referred to as a spatial subchannel of the MIMO channel. For a MIMO system not utilizing orthogonal frequency division modulation (OFDM), there is typically only one frequency subchannel and each spatial subchannel may be referred to as a "transmission channel". For a MIMO system utilizing OFDM, each spatial subchannel of each frequency subchannel may be referred to as a transmission channel.

[1027] For the example shown in FIG. 1, base station 104 concurrently communicates with terminals 106a through 106d (as indicated by the solid lines) via multiple antennas available at the base station. Inactive terminals 106e through 106h may receive pilot references and other signaling information from base station 104 (as indicated by the dashed lines), but are not transmitting or receiving user-specific data to/from the base station. The downlink (i.e., forward link) refers to transmissions from the base station to the terminals, and the uplink (i.e., reverse link) refers to transmissions from the terminals to the base station.

[1028] MIMO system 100 may be designed to implement any number of standards and designs for CDMA, TDMA, FDMA, and other multiple access schemes. The

CDMA standards include the IS-95, cdma2000, W-CDMA standards, and the TDMA standards include Global System for Mobile Communications (GSM). These standards are known in the art and incorporated herein by reference.

[1029] Aspects of the invention provide techniques to increase the performance of a wireless communication system. These techniques may be advantageously used to increase the uplink capacity of a multiple-access cellular system. In an aspect, scheduling schemes are provided to schedule data transmissions from terminals that employ single antenna (i.e., SIMO terminals) and/or terminals that employ multiple antennas (i.e., MIMO terminals). Both types of terminals may be supported simultaneously on the same carrier frequency. By allowing multiple data transmissions to occur simultaneously from multiple SIMO terminals, one or more MIMO terminals, or a combination thereof, the capacity of the system is increased relative to that achieved when only one terminal is allowed to transmit in a given time interval, as is typically performed in conventional time-division multiplexed (TDM) systems. The scheduling schemes are described in further detail below.

[1030] In another aspect, MIMO receiver processing techniques are used at the base station to increase system capacity. With MIMO, scheduled terminals transmit multiple independent data streams from a number of transmit antennas. If the propagation environment has sufficient scattering, the MIMO receiver processing techniques efficiently exploit the spatial dimensionality of the MIMO channel to support increased data rates for the terminals. At the MIMO receiver (i.e., the base station for the uplink), multiple receive antennas are used in conjunction with array signal processing techniques (described below) to recover the transmitted data streams from one or more terminals.

[1031] The MIMO receiver processing techniques can be used to increase the data rates of individual terminals, which correspondingly increases the capacity of the system. The MIMO receiver processing techniques can be used to process signals transmitted from multiple terminals equipped with single transmit antenna (e.g. SIMO terminals). From the base station's perspective, there is no discernable difference in processing N different signals from a single terminal (e.g., a single MIMO terminal) versus processing one signal from each of N different terminals (i.e., N SIMO terminals).

[1032] As shown in FIG. 1, the terminals may be randomly distributed in the base station's coverage area (or "cell"). Moreover, the link characteristics typically vary over time due to a number of factors such as fading and multipath. For simplicity, each terminal in the cell is assumed to be equipped with a single antenna. At a particular instant in time, the channel response between each terminal's antenna and the base station's array of N_R receive antennas is characterized by a vector $\underline{\mathbf{h}}_i$ whose elements are composed of independent Gaussian random variables, as follows:

$$\underline{\mathbf{h}}_i = \begin{bmatrix} h_{i,1} \\ h_{i,2} \\ \vdots \\ h_{i,N_R} \end{bmatrix}, \qquad \text{Eq (1)}$$

where $h_{i,j}$ is the channel response estimate from the i-th terminal to the j-th receive antenna at the base station. As shown in equation (1), the channel estimates for each terminal is a vector with N_R elements corresponding to the number of receive antennas at the base station. Each element of the vector $\underline{\mathbf{h}}_i$ describes the response for a respective transmit-receive antenna pair between the terminal and base station. For simplicity, equation (1) describes a channel characterization based on a flat fading channel model (i.e., one complex value for the entire system bandwidth). In an actual operating environment, the channel may be frequency selective (i.e., the channel response varies across the system bandwidth) and a more detailed channel characterization may be used (e.g., each element of the vector $\underline{\mathbf{h}}_i$ may include a set of values for different frequency subchannels or time delays).

[1033] Also for simplicity, it is assumed that the average received power from each terminal is normalized to achieve a common target energy-per-bit-to-total-noise-plus-interference ratio (E_b/N_t) after signal processing at the base station. This target E_b/N_t is often referred to as a power control setpoint (or simply, the setpoint) and is selected to provide a particular level of performance (e.g., a particular packet error rate (PER)). The common setpoint may be achieved by a closed loop power control mechanism in which the transmit power of each transmitting terminal may be adjusted (e.g., based on a power control signal from the base station). Alternatively, a unique setpoint may also be used for each terminal and the techniques described herein may be generalized to

cover this operating mode. Also, it is assumed that simultaneous transmissions from different terminals are synchronized so that the transmissions arrive at the base station within a prescribed time window.

[1034] The base station periodically estimates the channel response for "active" terminals, which are terminals desiring to transmit data during an upcoming or a future transmission interval. Active terminals may include terminals that are currently transmitting. The channel estimates may be facilitated in a number of ways such as, for example, with the use of pilot and/or data decision directed techniques, as described in further detail below.

[1035] Based on the available channel estimates, various scheduling schemes may be designed to maximize the uplink throughput by scheduling and assigning terminals to the available transmission channels such that they are allowed to transmit simultaneously. A scheduler can be designed and used to evaluate which specific combination of terminals provides the best system performance (e.g., the highest throughput) subject to any system constraints and requirements. By exploiting the spatial (and possibly frequency) "signatures" of the individual terminals (i.e., their channel response estimates), the average uplink throughput can be increased relative to that achieved with a single terminal. Furthermore, by exploiting the multi-user diversity, the scheduler can find combinations of "mutually compatible" terminals that can be allowed to transmit at the same time on the same channel, effectively enhancing system capacity relative to single-user scheduling or random scheduling for multiple users.

[1036] The terminals may be selected for data transmission based on various factors. One set of factors may relate to system constraints and requirements such as the desired quality of service (QoS), maximum latency, average data rate, and so on. Some or all of these factors may need to be satisfied on a per terminal basis (i.e., for each terminal) in a multiple access system. Another set of factors may pertain to system performance, which may be quantified by the average system throughput rate or some other indications of performance. These various factors are described in further detail below.

[1037] The scheduling schemes are designed to select the best combination of terminals for simultaneously transmission on the available transmission channels such

that system performance is maximized while conforming to the system constraints and requirements. If N_T terminals are selected for transmission and each terminal employs one antenna, the channel response matrix **H** corresponding to the selected set of terminals ($\underline{\mathbf{u}} = \{u_1, u_2, \ldots u_{Nt}\}$) may be expressed as:

$$\mathbf{H} = [\underline{\mathbf{h}}_1\ \underline{\mathbf{h}}_2\ \ldots\ \underline{\mathbf{h}}_{N_T}] = \begin{bmatrix} h_{1,1} & h_{2,1} & \cdots & h_{N_T,1} \\ h_{1,2} & h_{2,2} & \cdots & h_{N_T,2} \\ \vdots & \vdots & & \vdots \\ h_{1,N_R} & h_{2,N_R} & \cdots & h_{N_T,N_R} \end{bmatrix} . \qquad \text{Eq (2)}$$

[1038] In accordance with an aspect of the invention, a successive equalization and interference cancellation (or "successive cancellation") receiver processing technique is used at the base station to receive and process the transmissions from multiple terminals. This technique successively processes the N_R received signals a number of times (or iterations) to recover the signals transmitted from the terminals, with one transmitted signal being recovered for each iteration. For each iteration, the technique performs linear or non-linear processing (i.e., spatial or space-time equalization) on the N_R received signals to recover one of the transmitted signals, and cancels the interference due to the recovered signal from the received signals to derive "modified" signals having the interference component removed. The modified signals are then processed by the next iteration to recover another transmitted signal. By removing the interference due to each recovered signal from the received signals, the SNR improves for the transmitted signals included in the modified signals but not yet recovered. The improved SNR corresponds to improved performance for the terminal as well as the system. The successive cancellation receiver processing technique is described in further detail below.

[1039] When using the successive cancellation receiver processing technique to process the received signals, the SNR associated with each transmitting terminal is a function of the particular order in which the terminals are processed at the base station. In an aspect, the scheduling schemes take this into account in selecting the set of terminals to allow transmission.

[1040] FIG. 2 is a flow diagram of a process 200 to schedule terminals for transmission, in accordance with an embodiment of the invention. For clarity, the

overall process is first described and the details for some of the steps in the process are described subsequently.

[1041] Initially, the metrics to be used to select the "best" set of terminals for transmission are initialized, at step 212. Various performance metrics may be used to evaluate the terminal selections and some of these are described in further detail below. For example, a performance metric that maximizes system throughput may be used. Also, terminal metrics such as SNRs for the transmitted signals after processing at the base station (i.e., the "post-processed" signals) may also be used in the evaluation.

[1042] A (new) set of active terminals is then selected from among all active terminals desiring to transmit data in the upcoming transmission interval, at step 214. Various techniques may be used to limit the number of active terminals to be considered for scheduling, as described below. The specific set of terminals selected (e.g., $\underline{\mathbf{u}} = \{u_a, u_b, \ldots u_{Nt}\}$) forms a hypothesis to be evaluated. For each selected terminal u_i in the set, the channel estimates vector $\underline{\mathbf{h}}_i$ is retrieved, at step 216.

[1043] When the successive cancellation receiver processing technique is used at the base station, the order in which the terminals are processed directly impacts their performance. Thus, a particular (new) order is selected to process the terminals in the set, at step 218. This particular order forms a sub-hypothesis to be evaluated.

[1044] The sub-hypothesis is then evaluated and the terminal metrics for the sub-hypothesis are provided, at step 220. The terminal metrics may be the SNRs for the (post-processed) signals hypothetically transmitted from the terminals in the set. Step 220 may be achieved based on the successive cancellation receiver processing technique, which is described below in FIGS. 3A and 3B. The performance metric (e.g., the system throughput) corresponding to this sub-hypothesis is then determined (e.g., based on the SNRs for the post-processed signals from the terminals), at step 222. This performance metric is then used to update the performance metric corresponding to the current best sub-hypothesis, also at step 222. Specifically, if the performance metric for this sub-hypothesis is better than that of the current best sub-hypothesis, then this sub-hypothesis becomes the new best sub-hypothesis and the performance and terminal metrics corresponding to this sub-hypothesis are saved.

[1045] A determination is then made whether or not all sub-hypotheses for the current hypothesis have been evaluated, at step 224. If all sub-hypotheses have not been

evaluated, the process returns to step 218 and a different and not yet evaluated order for the terminals in the set is selected for evaluation. Steps 218 through 224 are repeated for each sub-hypothesis to be evaluated.

[1046] If all sub-hypotheses for a particular hypothesis have been evaluated, at step 224, a determination is made whether or not all hypotheses have been considered, at step 226. If all hypotheses have not been considered, the process returns to step 214 and a different and not yet considered set of terminals is selected for evaluation. Steps 214 through 226 are repeated for each hypothesis to be considered.

[1047] If all hypotheses for the active terminals have been considered, at step 226, then the results for the best sub-hypothesis are saved, the data rates for the terminals in the best sub-hypothesis are determined (e.g., based on their SNRs), and the scheduled transmission interval and data rates are communicated to the terminals prior to the scheduled transmission interval, at step 228. If the scheduling scheme requires other system and terminal metrics to be maintained (e.g. the average data rate over the past K transmission intervals, latency for data transmission, and so on), then these metrics are updated, at step 230. The terminal metrics may be used to evaluate the performance of the individual terminals, and are described in further detail below. The scheduling is typically performed for each transmission interval.

[1048] FIG. 3A is a flow diagram for a successive cancellation receiver processing scheme 220a whereby the processing order is imposed by an ordered set of terminals. This flow diagram may be used for step 220 in FIG. 2. The processing shown in FIG. 3A is performed for a particular sub-hypothesis, which corresponds to an ordered set of terminals (e.g., $\underline{\mathbf{u}} = \{u_a, u_b, \ldots u_{Nt}\}$). Initially, the first terminal in the ordered set is selected as the current terminal to be processed (i.e., $u_i = u_a$), at step 312.

[1049] For the successive cancellation receiver processing technique, the base station first performs linear (i.e., spatial) or non-linear (i.e., space-time) equalization on the received signals to attempt to separate the individual signals transmitted by the terminals in the set, at step 314. The linear or non-linear equalization may be achieved as described below. The amount of achievable signal separation is dependent on the amount of correlation between the signals transmitted, and greater signal separation may be obtained if these signals are less correlated. Step 314 provides N_T post-processed signals corresponding to the N_T signals transmitted by the terminals in the set. As part

of the linear or non-linear processing, the SNR corresponding to the post-processed signal for the current terminal u_i is also determined (e.g., in a manner described below).

[1050] The post-processed signal corresponding to terminal u_i is then further processed (i.e., "detected") to obtain a decoded data stream for the terminal, at step 316. The detection may include demodulating, deinterleaving, and decoding the post-processed signal to derive the decoded data stream.

[1051] At step 318, a determination is made whether or not all terminals in the set have been processed. If all terminals have been processed, then the SNRs of the terminals are provided, at step 326, and the receiver processing terminates. Otherwise, the interference due to terminal u_i on each of the received signals is estimated, at step 320. The interference may be estimated (e.g., as described below) based on the channel response matrix **H** for the terminals in the set. The estimated interference due to terminal u_i is then subtracted from the received signals to derive modified signals, at step 322. These modified signals represent estimates of the received signals if terminal u_i had not transmitted (i.e., assuming that the interference cancellation was effectively performed). The modified signals are used in the next iteration to process the transmitted signal for the next terminal in the set. The next terminal in the set is then selected as the current terminal u_i, at step 324. In particular, $u_i = u_b$ for the second iteration, $u_i = u_c$ for the third iteration, and so on, for the ordered set $\underline{\mathbf{u}} = \{u_a, u_b, \ldots u_{Nt}\}$.

[1052] The processing performed in steps 314 and 316 is repeated on the modified signals (instead of the received signals) for each subsequent terminal in the set. Steps 320 through 324 are also performed for each iteration except for the last iteration.

[1053] Using the successive cancellation receiver processing technique, for each hypothesis of N_T terminals, there are N_T factorial possible orderings (e.g., $N_T! = 24$ if $N_T = 4$). For each ordering of terminals within a given hypothesis (i.e., each sub-hypothesis), the successive cancellation receiver processing (step 220) provides a set of SNRs for the post-processed signals for the terminals, which may be expressed as:

$$\underline{\gamma}_{hyp,order} = \{\gamma_1, \gamma_2, \ldots, \gamma_{N_T}\} ,$$

where γ_i is the SNR after the receiver processing for the i-th terminal in the sub-hypothesis.

[1054] Each sub-hypothesis is further associated with a performance metric, $R_{hyp,order}$, which may be a function of various factors. For example, a performance metric based on the SNRs of the terminals may be expressed as:

$$R_{hyp,order} = f(\underline{\gamma}_{hyp,order}) \ ,$$

where $f(\cdot)$ is a particular positive real function of the arguments within the parenthesis.

[1055] Various functions may be used to formulate the performance metric. In one embodiment, a function of the achievable throughputs for all N_T terminals for the sub-hypothesis may be used, which may be expressed as:

$$f(\underline{\gamma}_{hyp,order}) = \sum_{i=1}^{N_T} r_i \ , \qquad \text{Eq (3)}$$

where r_i is the throughput associated with the i-th terminal in the sub-hypothesis, and may be expressed as:

$$r_i = c_i \cdot \log_2(1+\gamma_i) \ , \qquad \text{Eq (4)}$$

where c_i is a positive constant that reflects the fraction of the theoretical capacity achieved by the coding and modulation scheme selected for this terminal.

[1056] For each sub-hypothesis to be evaluated, the set of SNRs provided by the successive cancellation receiver processing may be used to derive the performance metric for that sub-hypothesis, e.g., as shown in equations (3) and (4). The performance metric computed for each sub-hypothesis is compared to that of the current best sub-hypothesis. If the performance metric for a current sub-hypothesis is better, then that sub-hypothesis and the associated performance metric and SNRs are saved as the metrics for the new best sub-hypothesis.

[1057] Once all sub-hypotheses have been evaluated, the best sub-hypothesis is selected and the terminals in the sub-hypothesis are scheduled for transmission in an upcoming transmission interval. The best sub-hypothesis is associated with a specific set of terminals. If successive cancellation receiver processing is used at the base station, the best sub-hypothesis is further associated with a particular receiver processing order at the base station. In all cases, the sub-hypothesis is further associated

with the achievable SNRs for the terminals, which may be determined based on the selected processing order.

[1058] The data rates for the terminals may then be computed based on their achieved SNRs, as shown in equation (4). Partial-CSI (which may comprise the data rates or the SNRs) may be reported to the scheduled terminals, which then use the partial-CSI to accordingly adjust (i.e., adapt) their data processing to achieve the desired level of performance.

[1059] The first scheduling scheme described in FIGS. 2 and 3A represents a specific scheme that evaluates all possible orderings of each possible set of active terminals desiring to transmit data in the upcoming transmission interval. The total number of potential sub-hypotheses to be evaluated by a scheduler can be quite large, even for a small number of active terminals. In fact, the total number of sub-hypotheses can be expressed as:

$$N_{sub-hyp} = N_T! \binom{N_U}{N_T} = \frac{N_U!}{(N_U - N_T)!} , \qquad \text{Eq (5)}$$

where N_U is the number of active terminals to be considered for scheduling. For example, if $N_U = 8$ and $N_T = 4$, then $N_{sub\text{-}hyp} = 1680$. An exhaustive search may be used to determine the sub-hypothesis that provides the optimal system performance, as quantified by the performance metric used to select the best sub-hypothesis.

[1060] A number of techniques may be used to reduce the complexity of the processing to schedule terminals. Some scheduling schemes based on some of these techniques are described below. Other schemes may also be implemented and are within the scope of the invention. These schemes may also provide high system performance while reducing the amount of processing required to schedule terminals.

[1061] In a second scheduling scheme, the terminals included in each hypothesis to be evaluated are processed in a particular order that is determined based on a particular defined rule. This scheme relies on the successive cancellation receiver processing to determine the specific ordering for processing the terminals in the hypothesis. For example and as described below, for each iteration, the successive cancellation receiver processing scheme can recover the transmitted signal having the best SNR after

equalization. In this case, the ordering is determined based on the post-processed SNRs for the terminals in the hypothesis.

[1062] FIG. 3B is a flow diagram for a successive cancellation receiver processing scheme 220b whereby the processing order is determined based on the post-processed SNRs. This flow diagram may also be used for step 220 in FIG. 2. However, since the processing order is determined based on the post-processed SNRs generated by the successive cancellation receiver processing, only one sub-hypothesis is effectively evaluated for each hypothesis and steps 218 and 224 in FIG. 2 may be omitted.

[1063] Initially, linear or non-linear equalization is performed on the received signals to attempt to separate the individual transmitted signals, at step 314. The SNRs of the transmitted signals after the equalization are then estimated (e.g., as described below), at step 315. In an embodiment, the transmitted signal corresponding to the terminal with the best SNR is selected and further processed (i.e., demodulated and decoded) to obtain a decoded data stream for the terminal, at step 316. At step 318, a determination is made whether or not all terminals in the hypothesis have been processed. If all terminals have been processed, then the order of the terminals and their SNRs are provided, at step 328, and the receiver processing terminates. Otherwise, the interference due to the terminal just processed is estimated, at step 320. The estimated interference is then subtracted from the received signals to derive the modified signals, at step 322. Steps 314, 316, 318, 320, and 322 in FIG. 3B correspond to identically numbered steps in FIG. 3A.

[1064] In a third scheduling scheme, the terminals included in each hypothesis are processed based on a specific order. With successive cancellation receiver processing, the SNR of an unprocessed terminals improves with each iteration, as the interference from each processed terminals is removed. Thus, on average, the first terminal to be processed will have the lowest SNR, the second terminal to be processed will have the second to lowest SNR, and so on. Using this knowledge, the processing order for the terminals may be specified for a hypothesis.

[1065] In one embodiment of the third scheduling scheme, the ordering for each hypothesis to be evaluated is based on the priority of the terminals in the hypothesis. Various factors may be used to determine the priority of the terminals, and some of these factors are described below. In this embodiment, the lowest priority terminal in

the hypothesis may be processed first, the next lowest priority terminal may be processed next, and so on, and the highest priority terminal may be processed last. This embodiment allows the highest priority terminal to achieve the highest SNR possible for the hypothesis, which supports the highest possible data rate. In this manner, the assignment of data rates to terminals may be effectively performed in order based on priority (i.e., the highest priority terminal is assigned the highest possible data rate).

[1066] In another embodiment of the third scheduling scheme, the ordering for each hypothesis to be considered is based on the user payload, latency requirements, emergency service priority, and so on.

[1067] In a fourth scheduling scheme, the terminals are scheduled based on their priority. The priority of each terminal may be derived based on one or more metrics (e.g., average throughput), system constraints and requirements (e.g., maximum latency), other factors, or a combination thereof, as described below. A list may be maintained for all active terminals desiring to transmit data in the upcoming transmission interval (which is also referred to as a "frame"). When a terminal desires to transmit data, it is added to the list and its metrics are initialized (e.g., to zero). The metrics of each terminal in the list are thereafter updated on each frame. Once a terminal no longer desires to transmit data, it is removed from the list.

[1068] For each frame, a number of terminals in the list may be considered for scheduling. The particular number of terminals to be considered may be based on various factors. In one embodiment, only the N_T highest priority terminals are selected to transmit on the N_T available transmission channels. In another embodiment, the N_X highest priority terminals in the list are considered for scheduling, with $N_U > N_X > N_T$.

[1069] FIG. 4 is a flow diagram for a priority-based scheduling scheme 400 whereby N_T highest priority terminals are considered for scheduling, in accordance with an embodiment of the invention. At each frame interval, the scheduler examines the priority for all active terminals in the list and selects the N_T highest priority terminals, at step 412. In this embodiment, the remaining $(N_U - N_T)$ terminals in the list are not considered for scheduling. The channel estimates $\underline{\mathbf{h}}$ for each selected terminal are retrieved, at step 414. Each sub-hypothesis of the hypothesis formed by the N_T selected terminals is evaluated, and the corresponding vector of SNRs, $\underline{\gamma}_{hyp,order}$, for the post-processed signals for each sub-hypothesis is derived, at step 416. The best sub-

hypothesis is selected, and data rates corresponding to the SNRs of the best sub-hypothesis are determined, at step 418. Again, the scheduled transmission interval and the data rates may be reported to the terminals in the hypothesis. The metrics of the terminals in the list and system metrics are then updated, at step 420. In one embodiment, the best sub-hypothesis may correspond to the one that comes closest to normalizing the priority of the terminals after their metrics are updated.

[1070] Various metrics and factors may be used to determine the priority of the active terminals. In an embodiment, a "score" may be maintained for each terminal in the list and for each metric to be used for scheduling. In one embodiment, a score indicative of an average throughput over a particular averaging time interval is maintained for each active terminal. In one implementation, the score $\phi_n(k)$ for terminal u_n at frame k is computed as a linear average throughput achieved over some time interval, and can be expressed as:

$$\phi_n(k) = \frac{1}{\mathrm{K}} \sum_{i=k-\mathrm{K}+1}^{k} r_n(i) / r_{\max} \quad , \qquad \text{Eq (6)}$$

where $r_n(i)$ is the realized data rate (in unit of bits/frame) for terminal u_n at frame i and may be computed as shown in equation (4). Typically, $r_n(i)$ is bounded by a particular maximum achievable data rate, r_{max}, and a particular minimum data rate (e.g., zero). In another implementation, the score $\phi_n(k)$ for terminal u_n in frame k is an exponential average throughput achieved over some time interval, and can be expressed as

$$\phi_n(k) = (1-\alpha) \cdot \phi_n(k-1) + \alpha \cdot r_n(k) / r_{\max} \quad , \qquad \text{Eq (7)}$$

where α is a time constant for the exponential averaging, with a larger value for α corresponding to a longer averaging time interval.

[1071] When a terminal desires to transmit data, it is added to the list and its score is initialized to zero. The score for each terminal in the list is subsequently updated on each frame. Whenever a terminal is not scheduled for transmission in a frame, its data rate is set to zero (i.e., $r_n(k)$ = 0) and its score is updated accordingly. If a frame is received in error by a terminal, the terminal's effective data rate for that frame is also set to zero. The frame error may not be known immediately (e.g., due to round trip delay

of an acknowledgment/negative acknowledgment (Ack/Nak) scheme used for the data transmission) but the score can be adjusted accordingly once this information is available.

[1072] The priority for the active terminals may also be determined based in part on system constraints and requirements. For example, if the maximum latency for a particular terminal exceeds a threshold value, then the terminal may be elevated to a high priority.

[1073] Other factors may also be considered in determining the priority of the active terminals. One such factor may be related to the type of data to be transmitted by the terminals. Delay sensitive data may be associated with higher priority, and delay insensitive may be associated with lower priority. Retransmitted data due to decoding errors for a prior transmission may also be associated with higher priority since other processes may be awaiting the retransmitted data. Another factor may be related to the type of data service being provided for the terminals. Other factors may also be considered in determining priority and are within the scope of the invention.

[1074] The priority of a terminal may be a function of any combination of (1) the score maintained for the terminal for each metric to be considered, (2) other parameter values maintained for system constraints and requirements, and (3) other factors. In one embodiment, the system constraints and requirements represent "hard values" (i.e., high or low priority, depending on whether or not the constraints and requirements have been violated) and the scores represent "soft values". For this embodiment, terminals for which the system constraints and requirements have not been met are immediately considered, along with other terminals based on their scores.

[1075] A priority-based scheduling scheme may be designed to achieve equal average throughput (i.e., equal QoS) for all terminals in the list. In this case, active terminals are prioritized based on their achieved average throughput, which may be determined as shown in equation (6) or (7). In this priority-based scheduling scheme, the scheduler uses the scores to prioritize terminals for assignment to the available transmission channels. The active terminals in the list may be prioritized such that the terminal with the lowest score is given the highest priority, and the terminal with the highest score is given the lowest priority. Other methods for ranking terminals may also

be used. The prioritization may also assign non-uniform weighting factors to the terminal scores.

[1076] For a scheduling scheme in which terminals are selected and scheduled for transmission based on their priority, it is possible for poor terminal groupings to occur occasionally. A "poor" terminal set is one that results in strong linear dependence in that hypothesized channel response matrix **H**, which then results in low overall throughput for each terminal in the set. When this happen, the priorities of the terminals may not change substantially over several frames. In this way, the scheduler may be stuck with this particular terminal set until the priorities change sufficiently to cause a change in membership in the set.

[1077] To avoid the above-described "clustering" effect, the scheduler can be designed to recognize this condition prior to assigning terminals to the available transmission channels, and/or detect the condition once it has occurred. A number of different techniques may be used to determine the degree of linear dependence in the hypothesized matrix **H**. These techniques include solving for the eigenvalues of **H**, solving for the SNRs of the post-processed signals using a successive cancellation receiver processing technique or a linear spatial equalization technique, and others. In addition, detection of this clustering condition is typically simple to implement. In the event that the clustering condition is detected, the scheduler can reorder the terminals (e.g., in a random manner) in an attempt to reduce the linear dependence in the matrix **H**. A shuffling scheme may also be devised to force the scheduler to select terminal sets that result in "good" hypothesized matrices **H** (i.e., ones that have minimal amount of linear dependence).

[1078] For priority-based scheduling schemes (e.g., the third and fourth schemes described above), the scores of the terminals are updated based on their assignments or non-assignments to transmission channels. In an embodiment, for all scheduling schemes, the supported data rates for the terminals are determined based on their SNRs and communicated to the terminals for use in the scheduled transmission interval. In this manner, the scheduled terminals can transmit at the data rates supported by the SNRs estimated for the terminals. The base station also knows which terminals to process in a given frame and in what order to process them.

[1079] Some of the scheduling schemes described above employ techniques to reduce the amount of processing required to schedule terminals. These and other techniques may also be combined to derive other scheduling schemes, and this is within the scope of the invention. For example, the N_X highest priority terminals may be considered for scheduling using the first, second, or third scheme.

[1080] More complex scheduling schemes may also be devised that may be able to achieve throughput closer to optimum. These schemes may be required to evaluate a larger number of hypotheses and sub-hypotheses in order to determine the best set of terminals for data transmission on a given channel (i.e., a time slot, a code channel, a frequency subchannel, and so on). Other scheduling schemes may also be designed to take advantage of the statistical distribution of the data rates achieved by each order of processing, as described above. This information may be useful in reducing the number of hypotheses to be evaluated. In addition, for some applications, it may be possible to learn which terminal groupings (i.e., hypotheses) work well by analyzing performance over time. This information may then be stored, updated, and used by the scheduler in future scheduling intervals.

[1081] For simplicity, various aspects and embodiments of the invention have been described for a communication system in which (1) N_T terminals are selected for transmission, with each terminal employing a single transmit antenna, (2) the number of transmit antennas is equal to the number of receive antennas (i.e., $N_T = N_R$), and (3) one receive antenna is used for each scheduled terminal. In this operating mode, each terminal is effectively assigned to a respective available spatial subchannel of the MIMO channel.

[1082] The terminals may also share the multiplex array of receive antennas, and this is within the scope of the invention. In this case, the number of transmit antennas for the scheduled terminals may be greater than the number of receive antennas at the base station, and the terminals would share the available transmission channels using another multiple access technique. The sharing may be achieved via time division multiplexing (e.g., assigning different fractions of a frame to different terminals), frequency division multiplexing (e.g., assigning different frequency subchannels to different terminals), code division multiplexing (e.g., assigning different orthogonal

codes to different terminals), or some other multiplexing schemes, including combinations of the aforementioned techniques.

[1083] For simplicity, various aspects and embodiments of the invention have been described for a system in which each terminal includes one antenna. However, the techniques described herein may also be applied to a MIMO system that includes any combination of single-antenna terminals (i.e., SIMO terminals) and multiple-antenna terminals (i.e., MIMO terminals). For example, a base station with four receive antennas may support transmissions from (1) a single 4x4 MIMO terminal, (2) two 2x4 MIMO terminals, (3) four 1x4 SIMO terminals, (4) one 2x4 MIMO terminals and two 1x4 SIMO terminals, or any other combination of terminals. The scheduler may be designed to seleet the best combination of terminals based on the hypothesized post-processed SNRs for an assumed set of simultaneous transmitting terminals, where the set can include any combination of SIMO and MIMO terminals.

[1084] The scheduling schemes described herein determine the SNRs for the terminals based on a partieular transmit power level from the terminals. For simplicity, the same transmit power level is assumed for all terminals (i.e., no power control of the transmit power). However, by controlling the transmit power of the terminals, the achievable SNRs may be adjusted. For example, by decreasing the transmit power of a particular terminal via power control, the SNR for this terminal is reduced, the interference due to this terminal would also be reduced, and other terminals may be able to achieve better SNRs. Thus, power control may also be used in conjunction with the scheduling schemes described herein, and this is within the scope of the invention.

[1085] The scheduling of terminals based on priority is also described in U.S. Patent Application Serial No. 09/675,706, entitled "METHOD AND APPARATUS FOR DETERMINING AVAILABLE TRANSMIT POWER IN A WIRELESS COMMUNICATION SYSTEM," filed September 29, 2000. Scheduling of data transmission for the uplink is also described in U.S. Patent No. 5,923,650, entitled "METHOD AND APPARATUS FOR REVERSE LINK RATE SCHEDULING," issued July 13, 1999, and incorporated herein by reference.

[1086] The scheduling schemes described herein incorporate a number of features and provide numerous advantages. Some of these features and advantages are described below.

[1087] First, the scheduling schemes support "mix mode operation" whereby any combination of SIMO and MIMO terminals may be scheduled to transmit on the reverse link. Each SIMO terminal is associated with a channel estimate vector $\underline{\mathbf{h}}$ shown in equation (1), and each MIMO terminal is associated with a set of vectors $\underline{\mathbf{h}}$, one vector for each transmit antenna and which may further correspond to an available transmission channel. The vectors for the terminals in each set may be ordered in the manner described above and evaluated.

[1088] Second, the scheduling schemes provide a schedule for each transmission interval that includes a set of (optimal or near optimal) "mutually compatible" terminals based on their spatial signatures. Mutual compatibility may be taken to mean coexistence of transmission on the same channel and at the same time given specific constraints regarding terminals data rate requirements, transmit power, link margin, capability between SIMO and MIMO terminals, and possibly other factors.

[1089] Third, the scheduling schemes support variable data rate adaptation based on the SNRs of the post-processed signals transmitted by the terminals. Each scheduled terminal is informed when to communicate, which data rate(s) to use (e.g., on a per transmit antenna basis), and the particular mode (e.g., SIMO, MIMO).

[1090] Fourth, the scheduling schemes can be designed to consider sets of terminals that have similar link margins. Terminals may be grouped according to their link margin properties. The scheduler may then consider combinations of terminals in the same "link margin" group when searching for mutually compatible spatial signatures. This grouping according to link margin may improve the overall spectral efficiency of the scheduling schemes compared to that achieved by ignoring the link margins. Moreover, by scheduling terminals with similar link margins to transmit, uplink power control may be more easily exercised (e.g., on the entire set of terminals) to improve overall spectral reuse. This may be viewed as a combination of the uplink adaptive reuse scheduling in combination with spatial division multiple access (SDMA) for SIMO/MIMO. Scheduling based on link margins is described in further detail in U.S. Patent Application Serial No. 09/532,492, entitled "METHOD AND APPARATUS FOR CONTROLLING TRANSMISSIONS OF A COMMUNICATIONS SYSTEM," filed March 30, 2000, and U.S. Patent Application Serial No. 09/848,937, entitled "METHOD AND APPARATUS FOR CONTROLLING UPLINK TRANSMISSIONS

OF A WIRELESS COMMUNICATION SYSTEM," filed May 3, 2001, both assigned to the assignee of the present application and incorporated herein by reference.

[1091] Fifth, the scheduling schemes may take into account the particular order in which terminals are processed when a successive cancellation receiver processing scheme is used at the base station. The successive cancellation receiver processing scheme provides improved SNRs for the post-processed signals, and the achievable SNRs are dependent on the order in which the transmitted signals are processed. The scheduling schemes can be used to optimize the order in which transmitted signals are processed. Since the processing order impacts the post-processed SNR, this allows the scheduler extra degrees of freedom.

Performance

[1092] The use of successive cancellation receiver processing technique at the base station to process multiple SIMO and/or MIMO transmissions from a number of terminals provides improved system performance (e.g., higher throughput). Simulations have been performed to quantify the possible improvement in system throughput with some of these techniques. In the simulation, the channel response matrix **H** coupling the array of transmit antennas and receive antennas is assumed to be composed of equal-variance, zero-mean Gaussian random variables (i.e., "independent complex Gaussian assumption"). The average throughput for a random selection of N_T $1 \mathrm{x} N_R$ channels is assessed. Note that throughput is taken to be 50% of the channel capacity as determined by Shannon's theoretical capacity limit.

[1093] FIG. 9A shows the average throughput associated with four receive antennas (i.e., $N_R = 4$) and various number of single-antenna terminals (i.e., $N_T = 1$, 2 and 4) for an independent complex Gaussian assumption in an interference limited environment (i.e., the interference power is much greater than the thermal noise power). The case of four transmit antennas (i.e., $N_T = 4$) has greater capacity than the case of one transmit antenna (i.e., $N_T = 1$), with the gains increasing with SNR. At very high SNR, the capacity of the $N_T = 4$ case approaches four times that of the $N_T = 1$ case. At very low SNRs, the gain between these two cases reduces and becomes negligible.

[1094] In a low or no interference environment (e.g., thermal noise limited), the throughput of the $N_T = 4$ case is even greater than that shown in FIG. 9A. In the

thermal noise limited environment, the interference power is low (e.g., zero) and the SNR achieved is essentially 6 dB greater than that given in FIG. 9A for the $N_T = 4$ case. As an example, when a single terminal is received at an SNR of 10 dB, the average throughput achieved for this terminal is 2.58 bps/Hz. When four terminals are permitted to transmit simultaneously, the total throughput achieved is equivalent to the $N_T = 4$ curve at an SNR $=10$ dB $+ 10\cdot\log_{10}(4) = 16$ dB. Thus, in the thermal noise limited environment, the total throughput for four terminals is 8.68 bps/Hz or approximately 3.4 times that of a single terminal transmitting.

[1095] In interference limited systems such as a cellular network, the throughput per cell afforded with multiple SIMO transmissions in conjunction with the SC receiver processing at the base station is a function of the SNR setpoint selected for the terminals. For example, at 10 dB SNR, the capacity is more than doubled when four 1x4 SIMO terminals are allowed to transmit simultaneously. At 20 dB SNR, the capacity increases a factor of 2.6 times that achieved with a single 1x4 terminal. However, the higher operating setpoint typically implies a larger frequency reuse factor. That is, the fraction of cells using the same frequency channel simultaneously may need to be reduced to achieve the required SNR corresponding to the higher operating setpoints, which may then cause the overall spectral efficiency (as measured in bps/Hz/cell) to decrease. In maximizing network capacity for this scheme, there is thus a basic tradeoff between the selection of the particular operating setpoint and the required frequency reuse factor.

[1096] FIG. 9B shows the sensitivity in cell throughput for a simulated network of cells with $N_T = 1$, 2, and 4 simultaneous terminals. Each cell site employs $N_R = 4$ receive antennas. All terminals are power controlled to achieve a given setpoint. Inspection shows that there exists a range of SNR setpoints for which the cell throughput for $N_T = 4$ terminals is more than double that achieved when only a single terminal is allowed to transmit.

[1097] Various innovative techniques described herein may also be applied for scheduling downlink data transmissions.

MIMO Communication System

[1098] FIG. 5 is a block diagram of base station 104 and terminals 106 within MIMO communication system 100. At a scheduled terminal 106, a data source 512 provides data (i.e., information bits) to a transmit (TX) data processor 514. For each transmit antenna assigned for data transmission, TX data processor 514 (1) encodes the data in accordance with a particular coding scheme, (2) interleaves (i.e., reorders) the coded data based on a particular interleaving scheme, and (3) maps the interleaved bits into modulation symbols. The encoding increases the reliability of the data transmission. The interleaving provides time diversity for the coded bits, permits the data to be transmitted based on an average SNR for the transmit antenna, combats fading, and further removes correlation between coded bits used to form each modulation symbol. The interleaving may further provide frequency diversity if the coded bits are transmitted over multiple frequency subchannels. In an aspect, the coding and symbol mapping may be performed based on control signals provided by a controller 534.

[1099] The encoding, interleaving, and signal mapping may be achieved based on various schemes. Some such schemes are described in U.S. Patent Application Serial No. 09/854,235, entitled "METHOD AND APPARATUS FOR PROCESSING DATA IN A MULTIPLE-INPUT MULTIPLE-OUTPUT (MIMO) COMMUNICATION SYSTEM UTILIZING CHANNEL STATE INFORMATION," filed May 11, 2001; U.S. Patent Application Serial No. 09/826,481, entitled "METHOD AND APPARATUS FOR UTILIZING CHANNEL STATE INFORMATION IN A WIRELESS COMMUNICATION SYSTEM," filed March 23, 2001; and U.S. Patent Application Serial No. 09/776,075, entitled "CODING SCHEME FOR A WIRELESS COMMUNICATION," filed February 1, 2001, all assigned to the assignee of the present application and incorporated herein by reference.

[1100] If multiple transmit antennas are used for data transmission, TX MIMO processor 520 receives and demultiplexes the modulation symbols from TX data processor 514 and provides a stream of modulation symbols for each transmission channel (e.g., each transmit antenna), one modulation symbol per time slot. TX MIMO processor 520 may further precondition the modulation symbols for each selected transmission channel if full CSI (e.g., the channel response matrix **H**) is available.

MIMO and full-CSI processing is described in further detail in U.S. Patent Application Serial No. 09/532,492, entitled "HIGH EFFICIENCY, HIGH PERFORMANCE COMMUNICATIONS SYSTEM EMPLOYING MULTI-CARRIER MODULATION," filed March 22, 2000, assigned to the assignee of the present application and incorporated herein by reference.

[1101] If OFDM is not employed, TX MIMO processor 520 provides a stream of modulation symbols for each antenna used for data transmission. And if OFDM is employed, TX MIMO processor 520 provides a stream of modulation symbol vectors for each antenna used for data transmission. And if full-CSI processing is performed, TX MIMO processor 520 provides a stream of preconditioned modulation symbols or preconditioned modulation symbol vectors for each antenna used for data transmission. Each stream is then received and modulated by a respective modulator (MOD) 522 and transmitted via an associated antenna 524.

[1102] At base station 104, a number of receive antennas 552 receive the transmitted signals, and each receive antenna provides a received signal to a respective demodulator (DEMOD) 554. Each demodulator (or front-end unit) 554 performs processing complementary to that performed at modulator 522. The modulation symbols from all demodulators 554 are then provided to a receive (RX) MIMO/data processor 556 and processed to recover the data streams transmitted by the scheduled terminals. RX MIMO/data processor 556 performs processing complementary to that performed by TX data processor 514 and TX MIMO processor 520 and provides decoded data to a data sink 560. In an embodiment, RX MIMO/data processor 556 implements the successive cancellation receiver processing technique to provide improved performance. The processing by base station 104 is described in further detail in the aforementioned U.S. Patent Application Serial Nos. 09/854,235 and 09/776,075.

[1103] For each active terminal 106, RX MIMO/data processor 556 further estimates the link conditions and derives CSI (e.g., post-processed SNRs or channel gain estimates). The CSI is then provided to a TX data processor 562 and a scheduler 564.

[1104] Scheduler 564 uses the CSI to perform a number of functions such as (1) selecting the set of best terminals for data transmission, (2) determining the particular order in which the signals from the selected terminals are to be recovered, and (3)

determining the coding and modulation scheme to be used for each transmit antenna of each scheduled terminal. Scheduler 564 may schedule terminals to achieve high throughput or based on some other performance criteria or metrics, as described above. For each scheduling interval, scheduler 564 provides a schedule that indicates which active terminals have been selected for data transmission and the assigned transmission parameters for each schedule terminal. The transmission parameters for each assigned transmit antenna of each scheduled terminal may include the date rate and coding and modulation schemes to be used. In FIG. 5, scheduler 564 is shown as being implemented within base station 104. In other implementation, scheduler 564 may be implemented within some other element of communication system 100 (e.g., a base station controller that couples to and interacts with a number of base stations).

[1105] A TX data processor 562 receives and processes the schedule, and provides processed data indicative of the schedule to one or more modulators 554. Modulator(s) 554 further condition the processed data and transmit the schedule to the terminals via a forward channel. The schedule may be reported by the terminal using various signaling and messaging techniques.

[1106] At each active terminal 106, the transmitted scheduling signal is received by antennas 524, demodulated by demodulators 522, and provided to a RX data processor 532. RX data processor 532 performs processing complementary to that performed by TX data processor 562 and recovers the schedule for that terminal (if any), which is then provided to controller 534 and used to control the data transmission by the terminal.

[1107] FIG. 6 is a block diagram of an embodiment of a terminal 106x capable of processing data for transmission to the base station based on CSI available to the terminal (e.g., as reported in the schedule by the base station). Terminal 106x is one embodiment of the transmitter portion of terminal 106 in FIG. 5. Terminal 106x includes (1) a TX data processor 514x that receives and processes information bits to provide modulation symbols and (2) a TX MIMO processor 520x that demultiplexes the modulation symbols for the N_T transmit antennas.

[1108] In the specific embodiment shown in FIG. 6, TX data processor 514x includes a demultiplexer 608 coupled to a number of channel data processors 610, one processor for each of the N_S transmission channels assigned for data transmission. Demultiplexer 608 receives and demultiplexes the aggregate information bits into a

number of (up to N_S) data streams, one data stream for each assigned transmission channel. Each data stream is provided to a respective channel data processor 610.

[1109] In the embodiment shown in FIG. 6, each channel data processor 610 includes an encoder 612, a channel interleaver 614, and a symbol mapping element 616. Encoder 612 receives and encodes the information bits in the received data stream in accordance with a particular coding scheme to provide coded bits. Channel interleaver 614 interleaves the coded bits based on a particular interleaving scheme to provide time diversity. And symbol mapping element 616 maps the interleaved bits into modulation symbols for the transmission channel used for transmitting the data stream.

[1110] Pilot data (e.g., data of known pattern) may also be encoded and multiplexed with the processed information bits. The processed pilot data may be transmitted (e.g., in a time division multiplexed (TDM) manner) in all or a subset of the transmission channels used to transmit the information bits. The pilot data may be used at the base station to perform channel estimation.

[1111] As shown in FIG. 6, the data encoding, interleaving, and modulation (or a combination thereof) may be adjusted based on the available CSI (e.g., as reported by the base station). In one coding and modulation scheme, adaptive encoding is achieved by using a fixed base code (e.g., a rate 1/3 Turbo code) and adjusting the puncturing to achieve the desired code rate, as supported by the SNR of the transmission channel used to transmit the data. For this scheme, the puncturing may be performed after the channel interleaving. In another coding and modulation scheme, different coding schemes may be used based on the reported CSI. For example, each of the data streams may be coded with an independent code. With this scheme, a successive cancellation receiver processing scheme may be used at the base station to detect and decode the data streams to derive a more reliable estimate of the transmitted data streams, as described in further detail below.

[1112] Symbol mapping element 616 can be designed to group sets of interleaved bits to form non-binary symbols, and to map each non-binary symbol into a point in a signal constellation corresponding to a particular modulation scheme (e.g., QPSK, M-PSK, M-QAM, or some other scheme) selected for the transmission channel. Each mapped signal point corresponds to a modulation symbol. The number of information bits that may be transmitted for each modulation symbol for a particular level of

performance (e.g., one percent packet error rate (PER)) is dependent on the SNR of the transmission channel. Thus, the coding and modulation scheme for each transmission channel may be selected based on the available CSI. The channel interleaving may also be adjusted based on the available CSI.

[1113] The modulation symbols from TX data processor 514x are provided to TX MIMO processor 520x, which is one embodiment of TX MIMO processor 520 in FIG. 5. Within TX MIMO processor 520x, a demultiplexer 622 receives (up to) N_S modulation symbol streams from N_S channel data processors 610 and demultiplexes the received modulation symbols into a number of (N_T) modulation symbol streams, one stream for each antenna used to transmit the modulation symbols. Each modulation symbol stream is provided to a respective modulator 522. Each modulator 522 converts the modulation symbols into an analog signal, and further amplifies, filters, quadrature modulates, and upconverts the signal to generate a modulated signal suitable for transmission over the wireless link.

[1114] A transmitter design that implements OFDM is described in the aforementioned U.S. Patent Application Serial Nos. 09/854,235, 09/826,481, 09/776,075, and 09/532,492.

[1115] FIG. 7 is a block diagram of an embodiment of base station 104x capable of implementing various aspects and embodiments of the invention. Base station 104x is one specific embodiment of the receive portion of base station 104 in FIG. 5 and implements the successive cancellation receiver processing technique to receive and recover the signals transmitted by the scheduled terminals. The transmitted signals from the terminals are received by each of N_R antennas 552a through 552r and routed to a respective demodulator (DEMOD) 554 (which is also referred to as a front-end processor). Each demodulator 554 conditions (e.g., filters and amplifies) a respective received signal, downconverts the conditioned signal to an intermediate frequency or baseband, and digitizes the downconverted signal to provide samples. Each demodulator 554 may further demodulate the samples with a received pilot to generate a stream of received modulation symbols, which is provided to a RX MIMO/data processor 556x.

[1116] In the embodiment shown in FIG. 7, RX MIMO/data processor 556x (which is one embodiment of RX MIMO/data processor 556 in FIG. 5) includes a number of

successive (i.e., cascaded) receiver processing stages 710, one stage for each of the transmitted data stream to be recovered by base station 104x. In one transmit processing scheme, one data stream is transmitted on each transmission channel assigned for data transmission, and each data stream is independently processed (e.g., with its own coding and modulation scheme) and transmitted from a respective transmit antenna. For this transmit processing scheme, the number of data streams to be recovered is equal to the number of assigned transmission channels, which is also equal to the number of transmit antennas used for data transmission by the scheduled terminals. For clarity, RX MIMO/data processor 556x is described for this transmit processing scheme.

[1117] Each receiver processing stage 710 (except for the last stage 710n) includes a channel MIMO/data processor 720 coupled to an interference canceller 730, and the last stage 710n includes only channel MIMO/data processor 720n. For the first receiver processing stage 710a, channel MIMO/data processor 720a receives and processes the N_R modulation symbol streams from demodulators 554a through 554r to provide a decoded data stream for the first transmission channel (or the first transmitted signal). And for each of the second through last stages 710b through 710n, channel MIMO/data processor 720 for that stage receives and processes the N_R modified symbol streams from the interference canceller 720 in the preceding stage to derive a decoded data stream for the transmission channel being processed by that stage. Each channel MIMO/data processor 720 further provides CSI (e.g., the SNR) for the associated transmission channel.

[1118] For the first receiver processing stage 710a, interference canceller 730a receives the N_R modulation symbol streams from all N_R demodulators 554. And for each of the second through second-to-last stages, interference canceller 730 receives the N_R modified symbol streams from the interference canceller in the preceding stage. Each interference canceller 730 also receives the decoded data stream from channel MIMO/data processor 720 within the same stage, and performs the processing (e.g., coding, interleaving, modulation, channel response, and so on) to derive N_R remodulated symbol streams that are estimates of the interference components of the received modulation symbol streams due to this decoded data stream. The remodulated symbol streams are then subtracted from the received modulation symbol streams to

derive N_R modified symbol streams that include all but the subtracted (i.e., canceled) interference components. The N_R modified symbol streams are then provided to the next stage. The order in which the transmitted signals are recovered is determined by the schedule, which may have taken into account the performance achieved by a specific order of processing to select the date rate and coding and modulation scheme for each transmitted signal.

[1119] In FIG. 7, a controller 740 is shown coupled to RX MIMO/data processor 556x and may be used to direct various steps in the successive cancellation receiver processing performed by processor 556x.

[1120] FIG. 7 shows a receiver structure that may be used in a straightforward manner when each data stream is transmitted over a respeetive transmit antenna (i.e., one data stream corresponding to each transmitted signal). In this case, each receiver processing stage 710 may be operated to recover one of the transmitted signals and provide the decoded data stream corresponding to the recovered transmitted signal. For some other transmit processing schemes, a data stream may be transmitted over multiple transmit antennas, frequency subchannels, and/or time intervals to provide spatial, frequency, and time diversity, respectively. For these schemes, the receiver processing initially derives a received modulation symbol stream for the transmitted signal on each transmit antenna of each frequency subchannel. Modulation symbols for multiple transmit antennas, frequency subchannels, and/or time intervals may then be combined in a complementary manner as the demultiplexing performed at the terminal. The stream of combined modulation symbols is then processed to provide the corresponding decoded data stream.

[1121] FIG. 8A is a block diagram of an embodiment of channel MIMO/data processor 720x, which is one embodiment of channel MIMO/data processor 720 in FIG. 7. In this embodiment, channel MIMO/data processor 720x includes a spatial/space-time processor 810, a CSI proeessor 812, a selector 814, a demodulation element 818, a de-interleaver 818, and a decoder 820.

[1122] Spatial/space-time processor 810 performs linear spatial processing on the N_R received signals for a non-dispersive MIMO channel (i.e., with flat fading) or space-time processing on the N_R received signals for a dispersive MIMO channel (i.e., with frequency selective fading). The spatial processing may be achieved using linear spatial

processing techniques such as a channel correlation matrix inversion (CCMI) technique, a minimum mean square error (MMSE) technique, and others. These techniques may be used to null out the undesired signals or to maximize the received SNR of each of the constituent signals in the presence of noise and interference from the other signals. The space-time processing may be achieved using linear space-time processing techniques such as a MMSE linear equalizer (MMSE-LE), a decision feedback equalizer (DFE), a maximum-likelihood sequence estimator (MLSE), and others. The CCMI, MMSE, MMSE-LE, and DFE techniques are described in further detail in the aforementioned U.S. Patent Application Serial No. 09/854,235. The DFE and MLSE techniques are also described in further detail by S.L. Ariyavistakul *et al.* in a paper entitled "Optimum Space-Time Processors with Dispersive Interference: Unified Analysis and Required Filter Span," IEEE Trans. on Communication, Vol. 7, No. 7, July 1999, and incorporated herein by reference.

[1123] CSI processor 812 determines the CSI for each of the transmission channels used for data transmission. For example, CSI processor 812 may estimate a noise covariance matrix based on the received pilot signals and then compute the SNR of the k-th transmission channel used for the data stream to be decoded. The SNR can be estimated similar to conventional pilot assisted single and multi-carrier systems, as is known in the art. The SNR for all transmission channels used for data transmission may comprise the CSI that is used by the base station to schedule data transmission. In certain embodiments, CSI processor 812 may further provide to selector 814 a control signal that identifies the particular data stream to be recovered by this receiver processing stage.

[1124] Selector 814 receives a number of symbol streams from spatial/space-time processor 810 and extracts the symbol stream corresponding to the data stream to be decoded. The extracted stream of modulation symbols is then provided to a demodulation element 814.

[1125] For the embodiment shown in FIG. 6 in which the data stream for each transmission channel is independently coded and modulated based on the channel's SNR, the recovered modulation symbols for the selected transmission channel are demodulated in accordance with a demodulation scheme (e.g., M-PSK, M-QAM) that is complementary to the modulation scheme used for the transmission channel. The

demodulated data from demodulation element 816 is then de-interleaved by a de-interleaver 818 in a complementary manner to that performed by channel interleaver 614, and the de-interleaved data is further decoded by a decoder 820 in a complementary manner to that performed by encoder 612. For example, a Turbo decoder or a Viterbi decoder may be used for decoder 820 if Turbo or convolutional coding, respectively, is performed at the terminal. The decoded data stream from decoder 820 represents an estimate of the transmitted data stream being recovered.

[1126] FIG. 8B is a block diagram of an interference canceller 730x, which is one embodiment of interference canceller 730 in FIG. 7. Within interference canceller 730x, the decoded data stream from the channel MIMO/data processor 720 within the same stage is re-encoded, interleaved, and re-modulated by a channel data processor 610x to provide remodulated symbols, which are estimates of the modulation symbols at the terminal prior to the MIMO processing (if any) and channel distortion. Channel data processor 610x performs the same processing (e.g., encoding, interleaving, and modulation) as that performed at the terminal for the data stream. The remodulated symbols are then provided to a channel simulator 830, which processes the symbols with the estimated channel response to provide estimates, $\hat{\underline{\mathbf{i}}}^k$, of the interference due the decoded data stream. The channel response estimate may be derived based on the pilot and/or data transmitted by the active terminals and in accordance with the techniques described in the aforementioned U.S. Patent Application Serial No. 09/854,235.

[1127] The N_R elements in the interference vector $\hat{\underline{\mathbf{i}}}^k$ correspond to the component of the received signal at each of the N_R receive antennas due to symbol stream transmitted on the *k*-th transmit antenna. Each element of the vector represents an estimated component due to the decoded data stream in the corresponding received modulation symbol stream. These components are interference to the remaining (not yet detected) transmitted signals in the N_R received modulation symbol streams (i.e., the vector $\underline{\mathbf{r}}^k$), and are subtracted (i.e., canceled) from the received signal vector $\underline{\mathbf{r}}^k$ by a summer 832 to provide a modified vector $\underline{\mathbf{r}}^{k+1}$ having the components from the decoded data stream removed. The modified vector $\underline{\mathbf{r}}^{k+1}$ is provided as the input vector to the next receiver processing stage, as shown in FIG. 7.

[1128] Various aspects of the successive cancellation receiver processing are described in further detail in the aforementioned U.S. Patent Application Serial No. **[Attorney Docket No. PA010210]**.

[1129] Receiver designs that do not employ the successive cancellation receiver processing technique may also be used to receive, process, and recover the transmitted data streams. Some such receiver designs are described in the aforementioned U.S. Patent Application Serial Nos. 09/776,075 and 09/826,481, and U.S. Patent Application Serial No. 09/539,157, entitled "HIGH EFFICIENCY, HIGH PERFORMANCE COMMUNICATIONS SYSTEM EMPLOYING MULTI-CARRIER MODULATION," filed March 30, 2000, assigned to the assignee of the present invention and incorporated herein by reference.

[1130] As used herein, the CSI may comprise any type of information that is indicative of the characteristics of the communication link. Various types of information may be provided as CSI for each scheduled terminal, and the CSI may be provided to the terminals in the schedule.

[1131] In one embodiment, the CSI comprises a data rate indicator for each transmit data stream. The quality of a transmission channel to be used for data transmission may be determined initially (e.g., based on the SNR estimated for the transmission channel) and a data rate corresponding to the determined channel quality may then be identified (e.g., based on a look-up table). The identified data rate is indicative of the maximum data rate that may be transmitted on the transmission channel for the required level of performance. The data rate is then mapped to and represented by a data rate indicator (DRI), which can be efficiently coded. For example, if (up to) seven possible data rates are supported, then a 3-bit value may be used to represent the DRI where, e.g., a zero may indicate a data rate of zero (i.e., no data transmission) and 1 through 7 may be used to indicate seven different data rates. In a typical implementation, the quality measurements (e.g., SNR estimates) are mapped directly to the DRI based on, e.g., a look-up table.

[1132] In another embodiment, the CSI comprises an indication of the particular processing scheme to be used at each scheduled terminal for each transmit data stream. In this embodiment, the indicator may identify the particular coding scheme and the

particular modulation scheme to be used for the transmit data stream such that the desired level of performance is achieved.

[1133] In yet another embodiment, the CSI comprises signal-to-noise-plus-interference ratio (SNR), which is derived as the ratio of the signal power over the noise plus interference power. The SNR is typically estimated and provided for each transmission channel used for data transmission (e.g., each transmit data stream), although an aggregate SNR may also be provided for a number of transmission channels. The SNR estimate may be quantized to a value having a particular number of bits. In one embodiment, the SNR estimate is mapped to an SNR index, e.g., using a look-up table.

[1134] In another embodiment, the CSI comprises power control information for each transmission channel. The power control information may include a single bit for each transmission channel to indicate a request for either more power or less power, or it may include multiple bits to indicate the magnitude of the change of power level requested. In this embodiment, the terminals may make use of the power control information fed back from the base station to adjust the data processing and/or the transmit power.

[1135] In yet another embodiment, the CSI comprises a differential indicator for a particular measure of quality for a transmission channel. Initially, the SNR or DRI or some other quality measurement for the transmission channel is determined and reported as a reference measurement value. Thereafter, monitoring of the quality of the transmission channel continues, and the difference between the last reported measurement and the current measurement is determined. The difference may then be quantized to one or more bits, and the quantized difference is mapped to and represented by the differential indicator, which is then reported. The differential indicator may indicate to increase or decrease the last reported measurement by a particular step size (or to maintain the last reported measurement). For example, the differential indicator may indicate that (1) the observed SNR for a particular transmission channel has increased or decreased by a particular step size, or (2) the data rate should be adjusted by a particular amount, or some other change. The reference measurement may be transmitted periodically to ensure that errors in the differential indicators and/or erroneous reception of these indicators do not accumulate.

[1136] In yet another embodiment, the CSI comprises signal power and interference plus noise power. These two components may be separately derived and provided for each transmission channel used for data transmission.

[1137] In yet another embodiment, the CSI comprises signal power, interference power, and noise power. These three components may be derived and provided for each transmission channel used for data transmission.

[1138] In yet another embodiment, the CSI comprises signal-to-noise ratio plus a list of interference powers for each observable interference term. This information may be derived and provided for each transmission channel used for data transmission.

[1139] In yet another embodiment, the CSI comprises signal components in a matrix form (e.g., $N_T \times N_R$ complex entries for all transmit-receive antenna pairs) and the noise plus interference components in matrix form (e.g., $N_T \times N_R$ complex entries). The terminal may then properly combine the signal components and the noise plus interference components for the appropriate transmit-receive antenna pairs to derive the quality for each transmission channel used for data transmission (e.g., the post-processed SNR for each transmitted data stream, as received at the base station).

[1140] Other forms of CSI may also be used and are within the scope of the invention. In general, the CSI includes sufficient information in whatever form that may be used to adjust the processing at each scheduled terminal such that the desired level of performance is achieved for the transmitted data streams.

[1141] The CSI may be derived based on the signals transmitted from the terminal and received at the base station. In an embodiment, the CSI is derived based on a pilot reference included in the transmitted signals. Alternatively or additionally, the CSI may be derived based on the data included in the transmitted signals.

[1142] In yet another embodiment, the CSI comprises one or more signals transmitted on the downlink from the base station to the terminals. In some systems, a degree of correlation may exist between the uplink and downlink (e.g. time division duplexed (TDD) systems where the uplink and downlink share the same band in a time division multiplexed manner). In these systems, the quality of the uplink may be estimated (to a requisite degree of accuracy) based on the quality of the downlink, which may be estimated based on a signal (e.g., a pilot signal) transmitted from the base

station. The pilot signal would then represent a means for which the terminals could estimate the CSI as observed at the base station.

[1143] The signal quality may be estimated at the base station based on various techniques. Some of these techniques are described in the following patents, which are assigned to the assignee of the present application and incorporated herein by reference:

- U.S. Patent No. 5,799,005, entitled "SYSTEM AND METHOD FOR DETERMINING RECEIVED PILOT POWER AND PATH LOSS IN A CDMA COMMUNICATION SYSTEM," issued August 25, 1998,
- U.S. Patent No. 5,903,554, entitled "METHOD AND APPARATUS FOR MEASURING LINK QUALITY IN A SPREAD SPECTRUM COMMUNICATION SYSTEM," issued May 11, 1999,
- U.S. Patent Nos. 5,056,109, and 5,265,119, both entitled "METHOD AND APPARATUS FOR CONTROLLING TRANSMISSION POWER IN A CDMA CELLULAR MOBILE TELEPHONE SYSTEM," respectively issued October 8, 1991 and November 23, 1993, and
- U.S. Patent No. 6,097,972, entitled "METHOD AND APPARATUS FOR PROCESSING POWER CONTROL SIGNALS IN CDMA MOBILE TELEPHONE SYSTEM," issued August 1, 2000.

Methods for estimating a single transmission channel based on a pilot signal or a data transmission may also be found in a number of papers available in the art. One such channel estimation method is described by F. Ling in a paper entitled "Optimal Reception, Performance Bound, and Cutoff-Rate Analysis of References-Assisted Coherent CDMA Communications with Applications," IEEE Transaction On Communication, Oct. 1999.

[1144] Various types of information for CSI and various CSI reporting mechanisms are also described in U.S. Patent Application Serial No. 08/963,386, entitled "METHOD AND APPARATUS FOR HIGH RATE PACKET DATA TRANSMISSION," filed November 3, 1997, assigned to the assignee of the present application, and in "TIE/EIA/IS-856 cdma2000 High Rate Packet Data Air Interface Specification", both of which are incorporated herein by reference.

[1145] The CSI may be reported to the scheduled terminal using various CSI transmission schemes. For example, the CSI may be sent in full, differentially, or a combination thereof. In one embodiment, CSI is reported periodically, and differential updates are sent based on the prior transmitted CSI. In another embodiment, the CSI is sent only when there is a change (e.g., if the change exceeds a particular threshold), which may lower the effective rate of the feedback channel. As an example, the date rate and/or coding and modulation scheme may be sent back (e.g., differentially) only when they change. Other compression and feedback channel error recovery techniques to reduce the amount of data to be fed back for CSI may also be used and are within the scope of the invention.

[1146] The elements of the transmitter and receiver systems may be implemented with one or more digital signal processors (DSP), application specific integrated circuits (ASIC), processors, microprocessors, controllers, microcontrollers, field programmable gate arrays (FPGA), programmable logic devices, other electronic units, or any combination thereof. Some of the functions and processing described herein may also be implemented with software executed on a processor.

[1147] Certain aspects of the invention may be implemented with a combination of software and hardware. For example, computations for the symbol estimates for the linear spatial equalization, the space-time equalization, and the derivation of the channel SNR may be performed based on program codes executed on a processor (controllers 540 in FIG. 5).

[1148] For clarity, the receiver architecture shown in FIG. 5 includes a number of receiving processing stages, one stage for each data stream to be decoded. In some implementations, these multiple stages may be implemented with a single hardware unit or a single software module that is re-executed for each stage. In this manner, the hardware or software may be time shared to simplify the receiver design.

[1149] Headings are included herein for reference and to aid in the locating certain sections. These heading are not intended to limit the scope of the concepts described therein under, and these concepts may have applicability in other sections throughout the entire specification.

[1150] The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various

modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

[1151] WHAT IS CLAIMED IS:

CLAIMS

1. A method for scheduling uplink data transmission for a plurality of terminals in a wireless communication system, comprising:

forming one or more sets of terminals for possible transmission on a channel, wherein each set includes a unique combination of terminals and corresponds to a hypothesis to be evaluated;

evaluating performance of each hypothesis;

selecting one of the one or more evaluated hypotheses based on their performance; and

scheduling the terminals in the selected hypothesis for data transmission on the channel.

2. The method of claim 1, further comprising:

determining data rates for each data stream of each terminal in the selected hypothesis, and

wherein data is transmitted at the determined data rates from the terminals in the selected hypothesis.

3. The method of claim 1, further comprising:

determining a coding and modulation scheme to be used for each data stream of each terminal in the selected hypothesis, and

wherein data is processed based on the determined coding and modulation schemes prior to transmission.

4. The method of claim 1, wherein each hypothesis is evaluated based in part on channel response estimates for each terminal in the hypothesis, wherein the channel response estimates are indicative of channel characteristics between the terminal and a receiving system.

5. The method of claim 1, wherein the channel response estimates comprise signal-to-noise-plus-interference ratios (SNRs).

6. The method of claim 1, wherein the evaluating includes computing a performance metric for each hypothesis.

7. The method of claim 6, wherein the performance metric is a function of throughput achievable by each of the terminals in the hypothesis.

8. The method of claim 6, wherein the hypothesis having the best performance metric is selected for scheduling.

9. The method of claim 1, further comprising:
prioritizing the terminals to be considered for scheduling.

10. The method of claim 9, further comprising:
limiting terminals to be processed for scheduling to a group of N highest priority terminals.

11. The method of claim 9, further comprising:
maintaining one or more metrics for each terminal to be considered for scheduling, and
wherein the priority of each terminal is determined based in part on the one or more metrics maintained for the terminal.

12. The method of claim 11, wherein one metric maintained for each terminal relates to an average throughput rate achieved by the terminal.

13. The method of claim 1, wherein the one or more sets are formed from terminals of a plurality of types, wherein each terminal of a first type is capable of transmitting a single data stream on a single transmission channel and each terminal of a second type is capable of transmitting multiple independent data streams on multiple transmission channels.

14. The method of claim 13, wherein each transmission channel corresponds to a spatial subchannel in the communication system.

15. The method of claim 1, wherein each of the one or more sets includes terminals having similar link margins.

16. The method of claim 1, further comprising:

forming one or more orderings of the terminals in each set, wherein each terminal ordering corresponds to a sub-hypothesis to be evaluated, and

wherein the performance of each sub-hypothesis is evaluated and one of the plurality of sub-hypotheses is selected based on their performance.

17. The method of claim 16, wherein the evaluating for each sub-hypothesis includes

processing signals hypothetically transmitted from the terminals in the sub-hypothesis based on spatial or space-time equalization to provide post-processed signals, and

determining signal-to-noise-plus-interference ratios (SNRs) for the post-processed signals for the terminals in the sub-hypothesis.

18. The method of claim 17, wherein the SNRs for the post-processed signals for the terminals are dependent on a particular ordering in which the terminals are processed, and wherein signals transmitted from the terminals are processed in an order defined by the selected sub-hypothesis.

19. The method of claim 17, wherein one sub-hypothesis is formed for each hypothesis, and wherein the ordering in the sub-hypothesis is based on the SNRs for the post-processed signals for the terminals in the hypothesis.

20. The method of claim 16, wherein the performance of each sub-hypothesis is evaluated based on a successive cancellation receiver processing scheme.

21. The method of claim 20, wherein the successive cancellation receiver processing scheme performs a plurality of iterations to recover signals hypothetically transmitted from the terminals in the sub-hypothesis, one iteration for each hypothetically transmitted signal to be recovered.

22. The method of claim 21, wherein each iteration includes

processing a plurality of input signals in accordance with a particular linear or non-linear processing scheme to provide a plurality of post-processed signals,

detecting the post-processed signal corresponding to the hypothetically transmitted signal being recovered in the iteration to provide a decoded data stream, and

selectively deriving a plurality of modified signals based on the input signals and having interference components due to the decoded data stream approximately removed, and

wherein the input signals for a first iteration are signals received from the terminals in the sub-hypothesis and the input signals for each subsequent iteration are the modified signals from a preceding iteration.

23. A method for scheduling data transmission for a plurality of terminals in a wireless communication system, comprising:

forming one or more sets of terminals for possible transmission on a channel, wherein each set includes a unique combination of terminals and corresponds to a hypothesis to be evaluated;

forming one or more orderings of the terminals in each set, wherein each terminal ordering corresponds to a sub-hypothesis to be evaluated;

evaluating performance of each sub-hypothesis;

selecting one of the plurality of evaluated sub-hypotheses based on their performance; and

scheduling the terminals in the selected sub-hypothesis for data transmission on the channel, and

wherein signals transmitted from the scheduled terminals are processed in an order defined by the selected sub-hypothesis.

24. The method of claim 23, wherein the evaluating includes

processing a signal hypothetically transmitted from each terminal in the sub-hypothesis based on a particular receiver processing scheme to provide a post-processed signal, and

determining a signal-to-noise-plus-interference ratio (SNR) for the post-processed signal for each terminal in the sub-hypothesis.

25. The method of claim 23, wherein one sub-hypothesis is formed for each hypothesis, and wherein the ordering in the sub-hypothesis is selected based on priority of terminals in the hypothesis.

26. The method of claim 25, wherein a lowest priority terminal in the hypothesis is processed first and a highest priority terminal is processed last.

27. The method of claim 23, wherein one sub-hypothesis is formed for each hypothesis, and wherein the ordering in the sub-hypothesis is selected to achieve the best performance for the hypothesis.

28. A multiple-input multiple-output (MIMO) communication system, comprising:

a base station comprising

a plurality of front-end processors configured to process a plurality of signals received from a plurality of terminals to provide a plurality of symbol streams,

at least one receive processor coupled to the front-end processors and configured to process the symbol streams in accordance with a successive cancellation receiver processing scheme to provide a plurality of decoded data streams, and to further derive channel state information (CSI) indicative of channel estimates for the plurality of terminals,

a scheduler configured to receive the CSI, select a set of one or more terminals for data transmission on an uplink, assign a particular order of processing for the one or more selected terminals, and provide a schedule for the one or more selected terminals and their transmission parameters, and

a transmit data processor operatively coupled to the receive processor and configured to process the schedule for transmission to the one or more selected terminals; and

one or more terminals, each terminal comprising

at least one demodulator configured to receive and process one or more signals from the base station to recover the transmitted schedule, and

a transmit data processor configured to adaptively process data for transmission to the base station based on the transmission parameters for the terminal included in the recovered schedule.

29. A base station in a multiple-input multiple-output (MIMO) communication system, comprising:

a plurality of front-end processors configured to process a plurality of signals received from a plurality of terminals to provide a plurality of received symbol streams;

at least one receive processor coupled to the front-end processors and configured to process the received symbol streams to provide a plurality of decoded data streams and to derive channel state information (CSI) associated with the decoded data stream;

a scheduler configured to receive the CSI, select a set of one or more terminals for data transmission on the uplink and provide a schedule for the one or more selected terminals and a set of one or more transmission parameters for each selected terminal; and

a transmit processor configured to receive and process the schedule for transmission to the plurality of terminals, and

wherein the one or more data streams from each scheduled terminal are adaptively processed prior to transmission based in part on the transmission parameters for the terminal included in the schedule.

30. The base station of claim 29, wherein the at least one receive processor is further operative to perform linear spatial processing on the received symbol streams.

31. The base station of claim 29, wherein the at least one receive processor is further operative to perform space-time processing on the received symbol streams.

32. The base station of claim 29, wherein the at least one receive processor is further operative to estimate a quality of each received symbol stream to derive the CSI for the associated decoded data stream.

33. The base station of claim 32, wherein the quality estimate is the signal-to-noise-plus-interference ratio (SNR) for the received symbol stream after spatial or space-time processing.

34. The base station of claim 29, wherein the set of one or more transmission parameters for each selected terminal includes a date rate for each data stream to be transmitted by the selected terminal.

35. The base station of claim 29, wherein the set of one or more transmission parameters for each selected terminal includes a coding and modulation scheme to be used for each data stream to be transmitted by the selected terminal.

36. A base station in a multiple-input multiple-output (MIMO) communication system, comprising:

a plurality of front-end processors configured to process a plurality of signals received from a plurality of terminals to provide a plurality of received symbol streams;

at least one receive processor coupled to the front-end processors and configured to process the received symbol streams to provide a plurality of decoded data streams, each receive processor including a plurality of processing stages, each stage configured to process input symbol streams to provide a respective decoded data stream and derive channel state information (CSI) associated with the decoded data stream;

a scheduler configured to receive the CSI, select a set of one or more terminals for data transmission on the uplink, assign a particular order of processing for the one or more selected terminals, and provide a schedule for the one or more selected terminals and a set of one or more transmission parameters for each selected terminal; and

a transmit processor configured to receive and process the schedule for transmission to the plurality of terminals, and

wherein the one or more data streams from each selected terminal are adaptively processed prior to transmission based in part on the set of one or more transmission parameters for the selected terminal.

37. The base station of claim 36, wherein each processing stage except a last stage includes

a channel processor configured to process the input symbol streams to provide a decoded data stream, and

a interference canceller configured to derive the modified symbol streams based on the decoded data stream and the input symbol streams.

38. The base station of claim 37, wherein each processing stage includes

a channel quality estimator operative to estimate a quality of the recovered symbol stream to derive the CSI for the associated decoded data stream.

39. The base station of claim 38, wherein the channel quality estimator is operative to estimate the signal-to-noise-plus-interference ratio (SNR) for the recovered symbol stream.

40. A terminal in a multiple-input multiple-output (MIMO) communication system, comprising:

at least one front-end processor configured to process at least one received signal to provide at least one received symbol stream;

at least one receive processor coupled to the at least one front-end processor and configured to process the at least one received symbol stream to recover a schedule for the terminal, wherein the schedule include an indication of a particular time interval in which the terminal is scheduled for data transmission and a set of one or more transmission parameters to be used by the terminal for the data transmission;

a transmit processor configured to receive and adaptively process data for transmission in accordance with the set of one or more transmission parameters, and

wherein the terminal is one of one or more terminals included in a set scheduled for data transmission in the particular time interval, and wherein the set of one or more

terminals scheduled for data transmission is selected from among one or more sets of terminals based on performance evaluated for each set.

41. The terminal of claim 40, wherein the recovered set of one or more transmission parameters includes a coding and modulation scheme to be used for each data stream to be transmitted by the terminal.

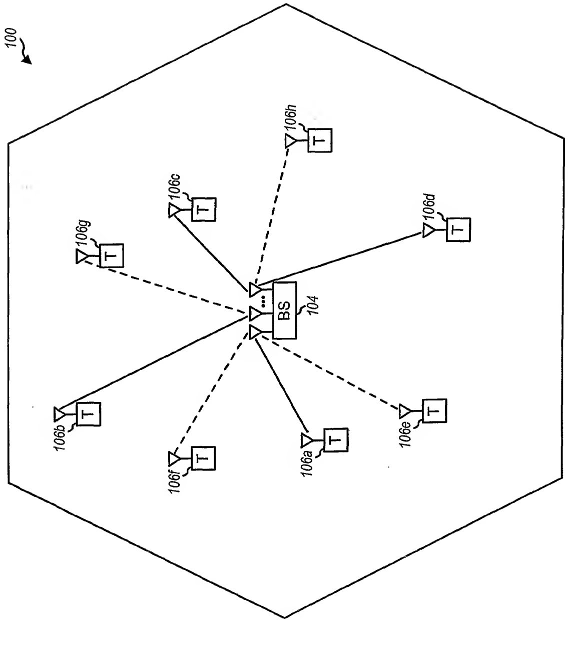


FIG. 1

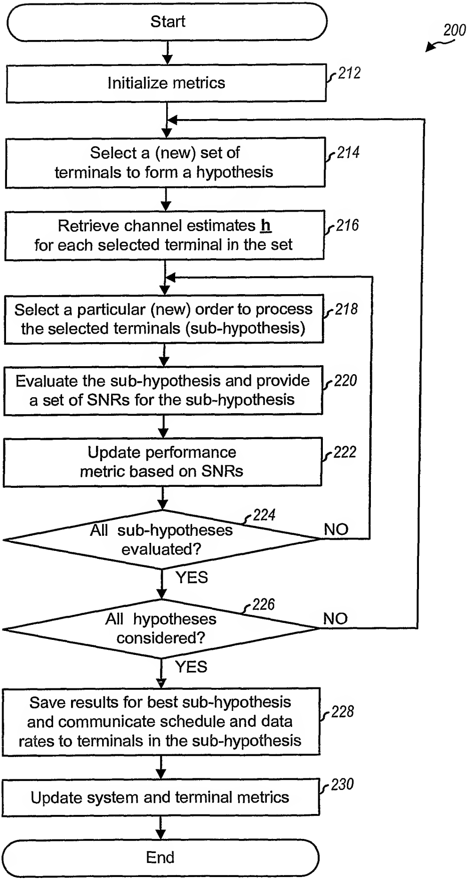

200
Start
Initialize metrics
212
Select a (new) set of terminals to form a hypothesis
214
Retrieve channel estimates h for each selected terminal in the set
216
Select a particular (new) order to process the selected terminals (sub-hypothesis)
218
Evaluate the sub-hypothesis and provide a set of SNRs for the sub-hypothesis
220
Update performance metric based on SNRs
222
All sub-hypotheses evaluated?
224
NO
YES
All hypotheses considered?
226
NO
YES
Save results for best sub-hypothesis and communicate schedule and data rates to terminals in the sub-hypothesis
228
Update system and terminal metrics
230
End

FIG. 2

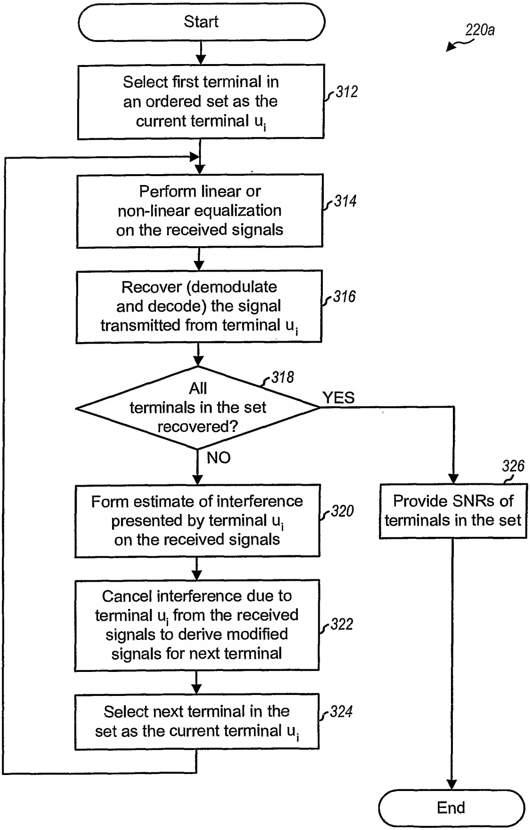

220a
Start
Select first terminal in an ordered set as the current terminal u_i
312
Perform linear or non-linear equalization on the received signals
314
Recover (demodulate and decode) the signal transmitted from terminal u_i
316
All terminals in the set recovered?
318
YES
NO
Form estimate of interference presented by terminal u_i on the received signals
320
Cancel interference due to terminal u_i from the received signals to derive modified signals for next terminal
322
Select next terminal in the set as the current terminal u_i
324
Provide SNRs of terminals in the set
326
End

FIG. 3A

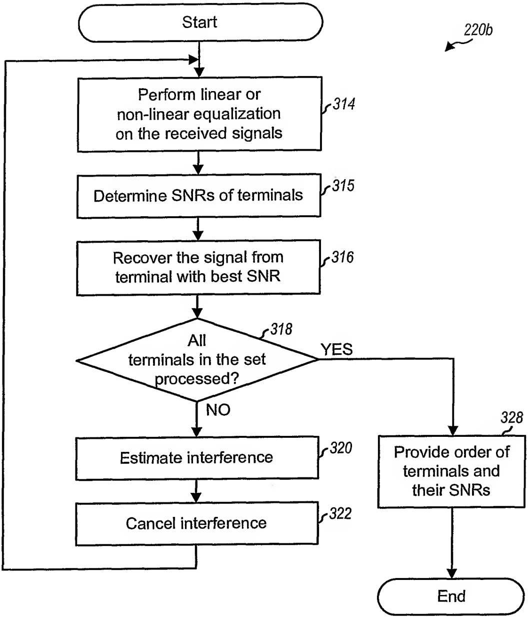

Start
220b
Perform linear or non-linear equalization on the received signals
314
Determine SNRs of terminals
315
Recover the signal from terminal with best SNR
316
All terminals in the set processed?
318
YES
NO
Estimate interference
320
Cancel interference
322
Provide order of terminals and their SNRs
328
End

FIG. 3B

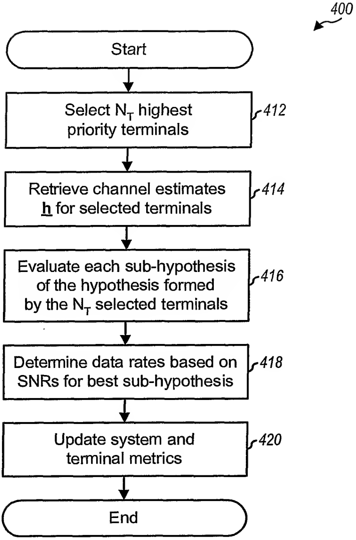

400
Start
Select N_T highest priority terminals
412
Retrieve channel estimates $\underline{h}$ for selected terminals
414
Evaluate each sub-hypothesis of the hypothesis formed by the N_T selected terminals
416
Determine data rates based on SNRs for best sub-hypothesis
418
Update system and terminal metrics
420
End

FIG. 4

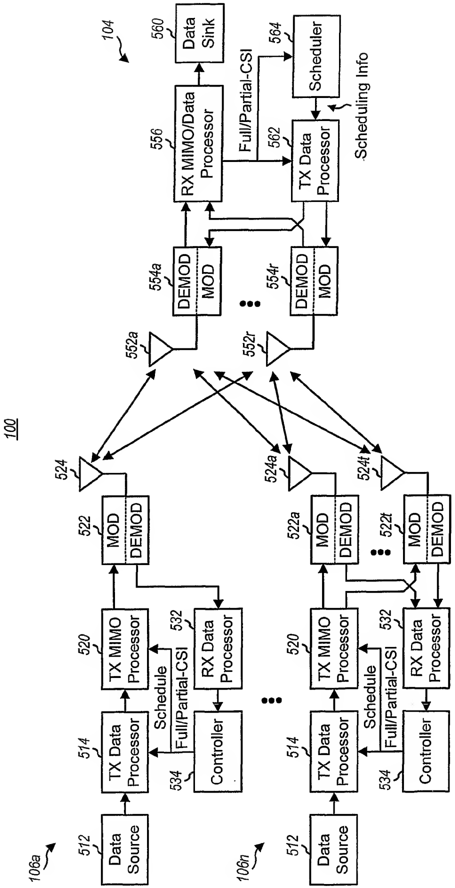

100
104
106a
106n
512
Data Source
514
TX Data Processor
520
TX MIMO Processor
522
MOD
DEMOD
524
532
RX Data Processor
534
Controller
Schedule
Full/Partial-CSI
522a
522t
524a
524t
552a
552r
554a
554r
DEMOD
MOD
556
RX MIMO/Data Processor
560
Data Sink
562
TX Data Processor
564
Scheduler
Full/Partial-CSI
Scheduling Info

FIG. 5

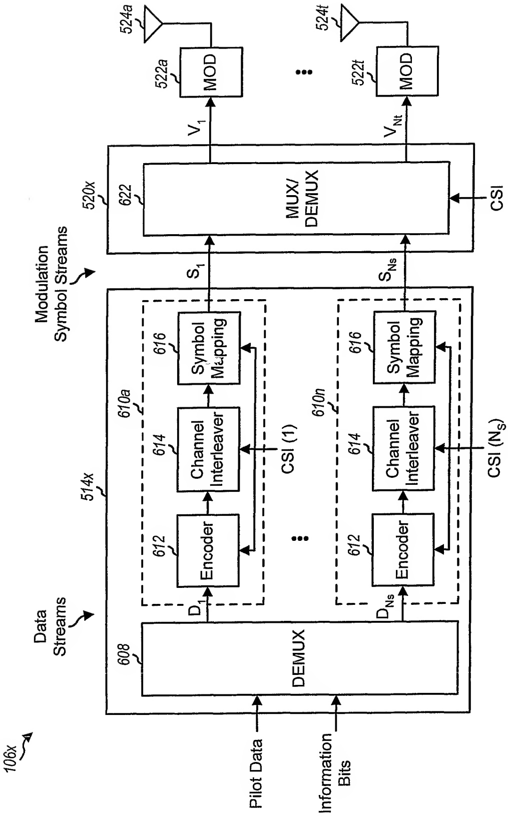

106x
Pilot Data
Information Bits
514x
608
DEMUX
Data Streams
D_1
D_{Ns}
610a
610n
612
Encoder
614
Channel Interleaver
616
Symbol Mapping
CSI (1)
CSI (N_S)
Modulation Symbol Streams
S_1
S_{Ns}
520x
622
MUX/ DEMUX
CSI
V_1
V_{Nt}
522a
522t
MOD
524a
524t

FIG. 6

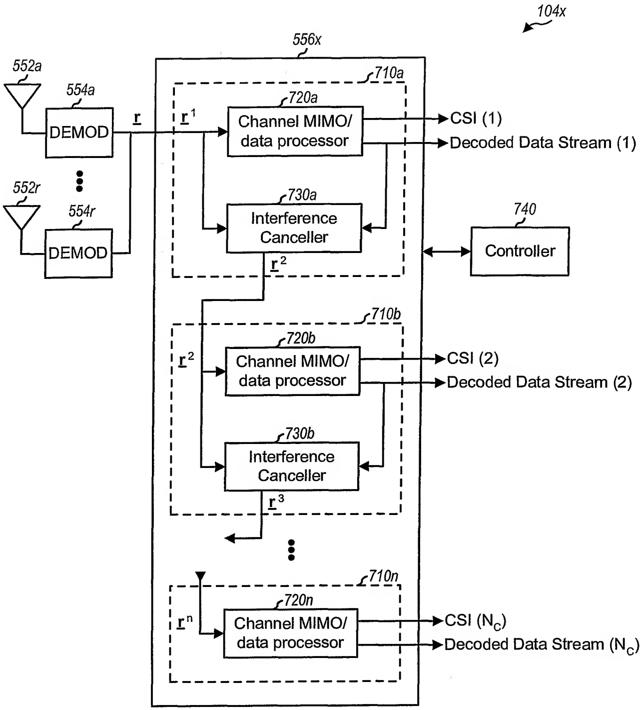

104x
556x
552a
554a
DEMOD
552r
554r
DEMOD
r
710a
720a
$\underline{r}^1$
Channel MIMO/ data processor
CSI (1)
Decoded Data Stream (1)
730a
Interference Canceller
$\underline{r}^2$
740
Controller
710b
720b
$\underline{r}^2$
Channel MIMO/ data processor
CSI (2)
Decoded Data Stream (2)
730b
Interference Canceller
$\underline{r}^3$
710n
720n
$\underline{r}^n$
Channel MIMO/ data processor
CSI (N_C)
Decoded Data Stream (N_C)

FIG. 7

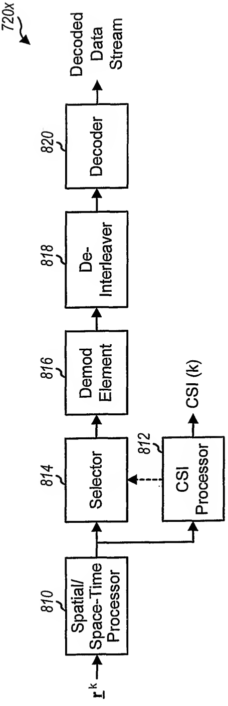

720x
$\underline{r}^k$
810
Spatial/ Space-Time Processor
814
Selector
812
CSI Processor
CSI (k)
816
Demod Element
818
De-Interleaver
820
Decoder
Decoded Data Stream

FIG. 8A

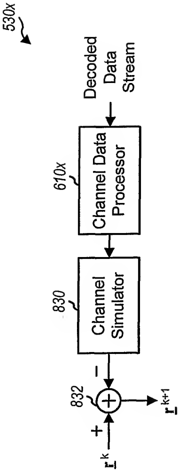
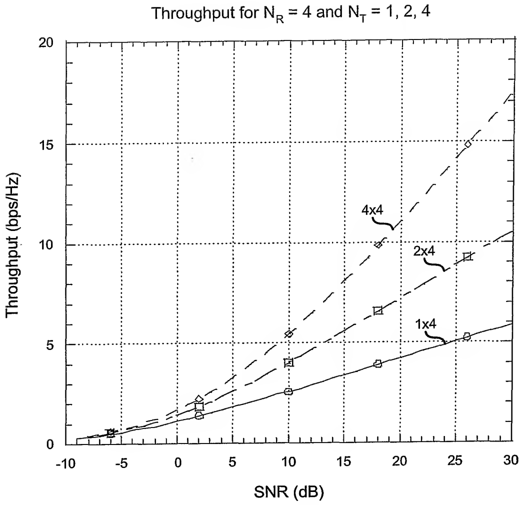

530x
$\underline{r}^k$
+
832
–
$\underline{r}^{k+1}$
830
Channel Simulator
610x
Channel Data Processor
Decoded Data Stream

FIG. 8B



Throughput for N_R = 4 and N_T = 1, 2, 4
Throughput (bps/Hz)
20
15
10
5
0
-10
-5
0
5
10
15
20
25
30
SNR (dB)
4x4
2x4
1x4

FIG. 9A

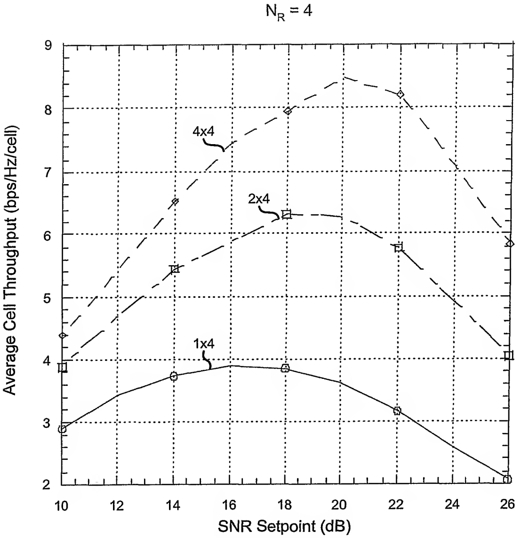

$N_R = 4$
4x4
2x4
1x4
Average Cell Throughput (bps/Hz/cell)
SNR Setpoint (dB)
2
3
4
5
6
7
8
9
10
12
14
16
18
20
22
24
26

FIG. 9B

INTERNATIONAL SEARCH REPORT

Interna Application No
PCT/US 02/15300

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/02 H04J15/00 H04L12/56 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B H04J H04L H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SANDHU S ET AL: "ANTENNA SELECTION FOR SPATIAL MULTIPLEXING SYSTEMS WITH LINEAR RECEIVERS" IEEE COMMUNICATIONS LETTERS, IEEE SERVICE CENTER, PISCATAWAY,US, US, vol. 4, no. 5, April 2001 (2001-04), pages 142-144, XP001103125 ISSN: 1089-7798 the whole document --- -/--	1-41

[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 September 2002	09/10/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Martinozzi, A

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	GORE D A ET AL: "SELECTING AN OPTIMAL SET OF TRANSMIT ANTENNAS FOR A LOW RANK MATRIXCHANNEL" 2000 IEEE INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH, AND SIGNAL PROCESSING. PROCEEDINGS. (ICASSP). ISTANBUL, TURKEY, JUNE 5-9, 2000, IEEE INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH, AND SIGNAL PROCESSING (ICASSP), NEW YORK, NY: IEEE, US, vol. 5 OF 6, 5 June 2000 (2000-06-05), pages 2785-2788, XP001035763 ISBN: 0-7803-6294-2 the whole document	1-41

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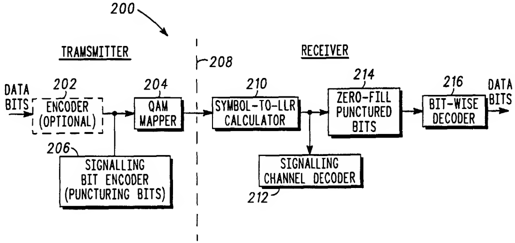
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** METHOD AND APPARATUS FOR ADAPTIVE SIGNALING AND PUNCTURING OF A QAM COMMUNICATIONS SYSTEM



(57) **Abstract:** A method and apparatus to adaptively puncture bits within QAM modulated data symbols transmitted in a communication system in order to effect a signaling channel. The method and apparatus utilize inherent characteristics of a particular mapping scheme for the QAM constellation to selectively puncture particular bits within a data symbol with signaling information and predetermined binary values to selectively increase the log-likelihood ratio gains of those particular bits punctured with the signaling information (206). The log-likelihood ratios are used to obtain the signaling information (210, 212, 214, 216) and, thus, increasing the gain of the log-likelihood ratios affords greater reliability for the signaling information without increasing the required system resources.

WO 02/100027 A1

METHOD AND APPARATUS FOR ADAPTIVE SIGNALING AND PUNCTURING OF A QAM COMMUNICATIONS SYSTEM

FIELD OF THE INVENTION

The present invention relates generally to communications systems, and more particularly to providing signaling through puncturing data symbols in a quadrature amplitude modulation communication system.

BACKGROUND OF THE INVENTION

Various wireless communication systems are known in the art. In multiple access wireless communications systems, such as code division multiple access (CDMA), a base station transmits multiple signals to individual mobile stations. The base station transmits multiple signals on a forward link that typically includes separate data and signaling channels. Similarly, the mobile station transmits data and signaling via a reverse link to the base station.

Signaling channels used in the communications system are often used for tasks such as power control and for sharing system information such as data frame structures. The signaling channels transmit at a low rate and require minimal latency and high reliability since the information transmitted via these channels is used to control the communications system. High latency or erroneous data in the signaling channels may cause the communications system to become unstable, which severely degrades the system capacity. This degradation may be further exacerbated in a multiple access communication system that achieves high data rates through use of quadrature amplitude modulation (QAM) along with Turbo encoders and decoders.

As mentioned previously, signaling channels may be implemented using a separate dedicated channel, which has its own convolutional encoders and decoders. Separate dedicated channels, however, require system resources that may be costly and not readily available and diminish resources available to other channels. Additionally, the separate dedicated channels incur a convolutional decoder delay. In order to reduce signaling overhead and avoid signaling delay, another method of implementing a signaling channel is to puncture bits on top of existing high data rate data channels. However, signaling accomplished through puncturing on top of existing data channels can degrade the performance of the high data rate channel and can also suffer a loss of reliability because there is no coding gain in this method. In this instance, attempts to increase reliability have included repetition of signaling bits, which consumes even greater amounts of system resources.

Therefore, a need exists for signaling channels in a high data rate QAM communication system that have high reliability and low decode delay while utilizing minimal system resources.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of an exemplary wireless communication system in accordance with an embodiment of the present invention.

FIG. 2 is a block diagram of communications system architecture in accordance with an embodiment of the present invention.

FIG. 3 is an illustration of a Gray-coded Karnaugh mapped QAM constellation utilized by the QAM mapper of FIG. 2.

FIG. 4 is a table showing the correlation of log-likelihood ratio gain for each bit position in a data symbol based on values of other bits within the data symbol in accordance with an embodiment of the present invention.

FIG. 5 is an illustration of various puncturing schemes utilized for puncturing particular bits in a data symbol in accordance with embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

To address the need for signaling channels in a high data rate QAM communication system that have high reliability and low decode delay while utilizing minimal system resources, a method and apparatus is provided that uses quadrature amplitude modulation (QAM) with bit-wise decoders where a log-likelihood ratio (LLR) is computed for each bit at a receiver portion. In particular, a transmitter in a communication system punctures bits of a data symbol that includes multiple data bits prior to modulation of the data symbol by a QAM mapper. The QAM mapper may employ a Gray-coded Karnaugh mapped constellation. In addition, the transmitter employs adaptive puncturing wherein specific bits within a data symbol are selectively punctured to achieve higher LLR gains that result from characteristics of the Karnaugh mapping scheme. The increased LLR gain affords higher reliability for signaling without consuming additional system resources.

The present invention can be better understood with reference to FIGs. 1-5. FIG. 1 illustrates an exemplary communications system 100 in accordance with an embodiment of the present invention. Communications system 100 includes a base

station 102 that is capable of transmitting multiple signals to each of multiple mobile subscriber units (MSs) 104 (one shown), such as cellular telephones, radiotelephones, or wireless data modems. Base station 102 transmits multiple signals on a forward link that includes data and signaling channels. Similarly, MS 104 transmits data and signaling via a reverse link to the base station 102.

FIG. 2 is a block diagram of an architecture of a communications system 200, such as communications system 100, that implements the signaling channel by adaptively puncturing signaling bits into a data symbol. Communications system 200 includes a transmitter (indicated by bracket), such as base station 102. Communications system 200 further includes a receiver (indicated by bracket), such as MS 104, on the other side of a transmission interface 208 that receives transmitted data symbols and that extracts the signaling bits from the punctured data symbols after the computation of a log-likelihood ratio (LLR) for each bit of a received data symbol. However, those who are of ordinary skill in the art realize that base station 102 and MS 104 are each capable of operating as either a transmitter or a receiver with respect to the embodiments of the present invention.

On the transmitter side of communications system 200, a stream of data, preferably in a binary format such as bits, is input to an encoder 202. Encoder 202 encodes the data stream pursuant to a prescribed data coding scheme and routes the encoded data to a QAM mapper 204. The type of encoder is not critical to, nor is specific encoding necessary for, the present invention. In another embodiment of the present invention, the data stream may be entered directly to QAM mapper 204. In either case, prior to inputting the data stream to QAM mapper 204, signaling data (i.e.,

signaling bits) is punctured into the data stream by a signal bit encoder 206 according to a predetermined puncturing scheme, which puncturing scheme is described in greater detail below.

QAM mapper 204 maps the input data stream to points in a multi-dimensional constellation. In order to map the data stream, QAM mapper 204 groups the input data stream into multiple groups of P bits, that is, into multiple P-tuples wherein each P-tuple may be thought of as a data symbol. QAM mapper 204 modulates each of the multiple P-tuples, or data symbols, by mapping the P-tuple to a corresponding point out of M possible points in a predetermined M-ary QAM constellation, wherein $M = 2^P$. To this end, the predetermined QAM constellation that includes the M possible points is defined within a multi-dimensional space, preferably a complex two-dimensional (I/Q) space. Each point within the two-dimensional space may be thought of as a vector sum of two scaled basis vectors. The two scaled basis vectors respectively correspond to an in-phase (I), or a real (r), component and a quadrature (Q), or an imaginary (i), component of the constellation point, or corresponding data symbol. The respective amplitudes of the two basis vectors used to define a particular point may be thought of as two-dimensional coordinates of the point.

Preferably the mapping scheme employed by QAM mapper 204 includes a Gray-coded Karnaugh mapping scheme, which is utilized to effect the predetermined puncturing scheme of the present application and simplifies hardware mapping and slicing functions. However, those who are of ordinary skill in the art realize that other QAM mapping schemes may be used herein without departing from the spirit and scope of the present invention. After modulation of each data symbol by QAM mapper 204, the modulated data symbols are transmitted via a communication interface 208 to the

receiver. Communication interface 208 is preferably wireless radio frequency (RF) transmission interface, but could also be any other transmission interface means such as land lines.

At the receiver of communications system 200, a Symbol-to-LLR calculator 210 receives each modulated data symbol and demodulates the modulated data symbol based on a determined log-likelihood ration (LLR) for each bit of the multiple bits corresponding to the modulated data symbol. Symbol-to-LLR calculator 210 determines an LLR for each bit based on a predetermined algorithm that is discussed in greater detail below. The demodulated data symbol is then output from Symbol-to-LLR calculator 210 to both a zero-fill block 214 and a signaling channel decoder 212. When a data symbol has been punctured, zero-fill block 214 fills punctured bit locations in the data symbol with a soft value of zero corresponding to an equal likelihood of a bit value of a “0” or a “1”. Each demodulated data symbol is then decoded by a bit-wise decoder 216 to recover the data bits encoded by encoder 202.

FIG. 3 is an illustration of an exemplary QAM constellation 300 in accordance with an embodiment of the present invention. QAM constellation 300 preferably comprises a Gray-coded Karnaugh constellation; however, mapping schemes other than Karnaugh mapping may also be used herein without departing from the spirit and scope of the present invention. QAM constellation 300 is a 64-QAM square constellation (i.e., $M = 64$) wherein each of the 64 constellation points corresponds to a particular P-tuple, or data symbol, of 6 bits (i.e., $P = 6$). However, those of ordinary skill in the art realize that any square Karnaugh mapped constellation for an M-ary QAM system may be used herein without departing from the spirit and scope of the present invention.

Each P-tuple, or 6-bit sequence, is of the form "$i_1\, q_1\, i_2\, q_2\, i_3\, q_3$", labeled from the most significant bit to least significant bit. Each "i" bit is independent of the imaginary, or quadrature (Q), axis 304 and each "q" bit is independent of the real, or in-phase (I), axis 302.

For example, for any given point in QAM constellation 300, movement to other points in a direction that is parallel to I-axis 302 produces a change in one or more "i" bits in the corresponding 6-bit sequence but does not produce a change in any of the "q" bits. As another example of this independence, for each point included in the first column of points to the right of Q-axis 304, bit i_1 in each corresponding data symbol is "0", bit i_2 in each corresponding data symbol is "0", and bit i_3 in each corresponding data symbol is "1". As a further illustration of this property of the Karnaugh mapped QAM data symbols, the lines shown at the top of, and to the left of, constellation 300 indicate subsets of constellation points where an indicated bit of a corresponding data symbol is a "1", and an absence of a line indicates of a subset of constellation points where an indicated bit of a corresponding data symbol is a "0". For example, the subset of points in constellation 300 wherein the bit i_1 of a corresponding data symbol is a "1" lies in the left hand side of the I/Q plane whereas the subset of points wherein the bit i_1 of a corresponding data symbol is a "0" lies in the right hand side of the I/Q plane.

Symbol-to-LLR calculator 210 determines an LLR for each of the bits within a data symbol to determine whether the bit is more likely to be a "0" or a "1". For a received data symbol y received at time k (i.e., y_k), the LLR of a j-th bit of the received symbol is determined by the following relationship:

$$LLR(u_{k,j}) = \log\left\{\frac{P(u_{k,j} = 0 \mid y_k)}{P(u_{k,j} = 1 \mid y_k)}\right\} \qquad (1)$$

where "$u_{k,j}$" corresponds to a hypothesized j-th bit of the transmitted data symbol based on the received symbol y_k, "$P(u_{k,j} = 0 \mid y_k)$" corresponds to a probability that the hypothesized j-th bit is a value "0" given the received data symbol y_k, and "$P(u_{k,j} = 1 \mid y_k)$" corresponds to a probability that the hypothesized j-th bit is a value "1" given the received data symbol y_k.

Equation (1) reduces to the expression:

$$LLR(u_{k,j}) = \log\left\{\frac{\sum_{u_k : u_{k,j}=0} P(y_k \mid u_k)}{\sum_{u_k : u_{k,j}=1} P(y_k \mid u_k)}\right\} \qquad (2)$$

where it is assumed that all transmitted data symbols are equiprobable. The probability "P" can then be represented by the following relationship:

$$P(y_k \mid u_k) = p(y_k^r, y_k^i \mid u_k^r, u_k^i) = p(y_k^r \mid u_k^r)\,p(y_k^i \mid u_k^i) \qquad (3)$$

where "r" corresponds to the real component, and "i" corresponds to the imaginary component, of each of a data symbol u_k, selected as described below, and the received data symbol y_k, and where perfect channel correction is assumed such that the real component is independent of the imaginary component.

Assuming additive Gaussian noise, the equation (3) can be rewritten as the following expression:

$$P(y_k \mid u_k) = \frac{1}{2\pi\sigma^2} \exp\frac{-D_k^2}{2\sigma^2} \qquad (4)$$

where the parameter D_k^2 is the squared Euclidean distance in the complex I/Q plane between a point corresponding to the received data symbol y_k and a data symbol, that is,

u_k, corresponding to one of the M points in the QAM constellation, such as constellation 300, selected as described below. It should be noted that the point in the complex I/Q plane corresponding to received data symbol y_k is unlikely to be one of the M points in the QAM constellation. The parameter σ^2 is the variance of the Gaussian noise.

With respect to each bit of the received data symbol y_k, two points and corresponding data symbols u_k are selected as follows from the QAM constellation of M points. A first point corresponds to the data symbol u_k whose j-th bit, that is, $u_{k,j}$, is a value "0", and which point, out of all of the constellation points whose j-th bit is a "0", is nearest to the point corresponding to y_k. A second point corresponds to the data symbol u_k whose j-th bit, *that is,* $u_{k,j}$, is a value "1", and which point, out of all of the constellation points whose j-th bit is a "1", is nearest to the point corresponding to y_k.

For each constellation point and corresponding data symbol selected as described above, a squared Euclidean distance D_k^2 between the point and a point corresponding to the received data symbol y_k can be calculated by summing the squares of the differences between the real (r) components, and between the imaginary (i) components, of the points, as represented by the following relationship:

$$D_k^2 = |y_k - u_k|^2 = (y_k^r - u_k^r)^2 + (y_k^i - u_k^i)^2 \qquad (5)$$

Substituting equation (4) into equation (2) allows calculation of the LLR based on the squared Euclidean distances and yields the following expression:

$$LLR(u_{k,j}) = \log \sum_{u_k:u_{k,j}=0} e^{\frac{-D_k^2}{2\sigma^2}} - \log \sum_{u_k:u_{k,j}=1} e^{\frac{-D_k^2}{2\sigma^2}} \qquad (6)$$

Equation (6) may then be approximated by simply taking the difference between the minimum squared distances between the received data symbol y_k and each of the two

selected data symbols u_k, having respective j-th bit values of "1" and "0". That is, equation (6) may be reduced to the following expression to approximate the LLR:

$$LLR(u_{k,j}) = \min_{u_k : u_{k,j}=1} [D_k^2] - \min_{u_k : u_{k,j}=0} [D_k^2] \quad (7)$$

By employing equation (7), the receiver of communication system 200 can determine an LLR with respect to the j-th bit of the received data symbol. Based on the LLR, the receiver can then determine a value of the j-th bit of the transmitted data symbol, thereby recovering the transmitted data symbol based on the received data symbol. The process of determining an LLR for the j-th bit of the received data symbol may be summarized in the following steps:

a) determining a first minimum squared Euclidean distance between the point corresponding to the received data symbol y_k and a nearest constellation point whose j-th bit, that is, $u_{k,j}$, is a value "1",

b) determining a second minimum squared Euclidean distance between the point corresponding to the received data symbol y_k and a nearest constellation point whose j-th bit, that is, $u_{k,j}$, is a "0", and

c) determining a difference between the first minimum squared Euclidean distance and the second minimum squared Euclidean distance.

If the difference is positive, then the j-th bit of the transmitted data symbol is most likely a binary value of "0". If the difference is negative, then the j-th bit is most likely a binary value of "1". These computed LLR values can, in turn, be fed into a convolutional decoder or a Turbo decoder, for example, that then determines the most likely sequence of bits. As an alternative, a simple slicer may be used to decode each bit by simply taking the sign of the LLR.

Several properties of the particular LLRs computed arise from using a Karnaugh-mapped construction of a QAM constellation, such as QAM constellation 300. For example, when a 6-bit data symbol is being mapped to a point in the QAM constellation, the LLRs of the even bits (i.e., q_1, q_2, and q_3) are independent from the LLRs of the odd bits (i.e., i_1, i_2, or i_3). Hence, whether the value of an odd bit "i" is a "1" or "0", it has no effect on the LLR of an even bit "q", and vice versa. Furthermore, the odd bits (i.e., i_1, i_2, or i_3) normally determine a position in the I-axis direction, which has no effect on the LLR for any even bit q_1, q_2, or q_3 since all of the even bits "q" at a particular location in the Q-axis direction will have the same bit value irrespective of where the data symbol lies along the I-axis. It is noted, however, the value of the odd bit or even bit can effect the LLR for the other odd or even bits, respectively.

Another feature that arises from utilizing a Karnaugh-mapped QAM constellation is that the two most significant bits (i.e., i_1 and q_1) have a higher average LLR than the lesser significant bits (i.e., i_2 and q_2). These middle bits, in turn, have a higher average LLR than the two least significant bits (i.e., i_3 and q_3). The reason for the differing average LLRs from the most significant to the least significant bits is due to the fact that the most significant bits i_1 and q_1 have the largest continuous coverage in the Karnaugh map (e.g., four columns or rows of points, or corresponding data symbols, as are seen in FIG. 3), whereas lesser significant bits i_2 and q_2 for example, have lesser coverage (e.g., two rows or columns of points or corresponding data symbols). The least significant bits i_3 and q_3 have the least coverage in the Karnaugh map given a data symbol having particular values of the most significant and lesser

significant bits, wherein the coverage is only one row or column of points or corresponding data symbols. Thus, the least significant bits i_3 and q_3 will always have an LLR associated with the distance of one point or corresponding data symbol. Similarly the lesser significant bits i_2 and q_2 will have LLRs associated with distances of one or two data symbols and the most significant bits i_1 and q_1 will have LLRs associated with distances of 1, 2, 3 or 4 points or corresponding data symbols.

The above-described properties of a Karnaugh mapped QAM constellation can be utilized to implement an adaptive puncturing scheme to transmit signaling information via a punctured data symbol in a simple and efficient manner. That is, bits selected to be punctured with signaling information may be chosen to yield the highest LLR or, alternatively, a minimally acceptable LLR gain that will effect a requisite level of reliability for transmitting the signaling information. The greater the value of the LLR, the greater a level of noise that is required to cause a bit error. Hence, higher LLRs are more immune to noise introduced during transmission of the data symbols.

FIG. 4 illustrates a table of LLR gains of bit positions and values for the Karnaugh mapped, Gray-coded constellation of FIG.3 assuming a noiseless environment. For purposes of clarity and assuming a 64-QAM system as an example, the 6 bits in a data symbol having the bit sequence "$i_1\, q_1\, i_2\, q_2\, i_3\, q_3$" are hereinafter referred to as corresponding sequential bit positions "$b_5\, b_4\, b_3\, b_2\, b_1\, b_0$". Thus, for bit positions b_0 and b_1, which are the least significant bits, the table in FIG. 4 illustrates that the values of these bits do not affect the magnitude of the LLR for these bits. However, the values of bit positions b_0 and b_1 affect the LLRs of the other bits in the data symbol. Thus, if these bits are punctured, a resultant gain in magnitude of the

LLRs of the other bits occurs . For instance, when bit b_0 is a "0" the resultant LLR for bit b_2 is a minimal value of +/– 4 D^2. However, when bit b_0 is a "1" the resultant magnitude for bit b_2 increases to +/– 16 D^2. Similarly for odd bit b_3 the LLR depends on the value of odd bit b_1.

For the most significant bit positions b_4 and b_5, various combinations of values of the least significant and lesser significant bits yield varying effects on the LLRs of the most significant bits. As may be seen in the table of FIG. 4, when both the lesser and least significant bits are of value "1" the most significant gain in the LLR is effected whereas when the lesser significant bit has a value of zero and the least significant bit has a value of one (i.e., a bit combination resulting in a data symbol that corresponds to a constellation point that is closest to an axis), the LLR magnitude is at the minimal value of +/– 4 D^2.

Based on the known LLR values corresponding to particular combinations of bits in the data symbol, a data symbol having particular bit values may be punctured in order to achieve a desired LLR and a desired level of reliability for the signaling bits punctured within the symbol. Therefore, a data symbol may be punctured periodically at a known time such that the receiver is aware of where the punctured bits are located. For example, of the 6 bits comprising a transmitted data symbol that is modulated based on a 64-QAM system, one of the most significant bits (e.g., b_5) is punctured since the most significant bits inherently have average LLRs superior to the lower four bits in the data symbol as was illustrated in the table of FIG. 4. By simply puncturing the most significant bit, a resultant average LLR magnitude of 30 D^2 is achieved, which is superior to the average LLR magnitude of 14.67 D^2 for all bits and corresponds to a 6.2

dB gain. FIG. 5 illustrates three possible bit sequences for a punctured data symbol where "X" indicates the punctured signaling bit that carries the signaling information (i.e., the signaling channel). In the first case, most significant odd bit b_5 is shown punctured without regard to the values of the other odd bits b_3 and b_1. As discussed previously, this results in an average LLR magnitude of 30 D^2 (i.e., the average of the four LLR values corresponding to the four possible combinations of bits b_3 and b_1).

If a higher degree of reliability is required for the signaling channel the bit b_3 may be punctured with a binary value of "1" as indicated in the second sequence of FIG. 5, which will raise the average LLR magnitude for the signaling bit (i.e., b_5) to 50 D^2 (i.e., the average of the LLR values 64 D^2 and 36 D^2 for the two possibilities where bit b_1 is a "1" or a "0"). The increase in the LLR magnitude to an average of 50 D^2 corresponds to a 10.6 dB gain. Similarly, in order to achieve the highest degree of reliability possible for the 64-QAM system illustrated, both odd bits b_3 and b_1 may be punctured with a binary value of "1" as shown the third sequence illustrated in FIG. 5. This will result in raising the average LLR magnitude to 64 D^2 for signaling bit b_5, which corresponds to a 12.8 dB gain.

It is noted that the bit sequence described above is an arbitrary sequence and that other bit sequences, as well as other QAM mapping schemes, may be employed herein without departing from the spirit and scope of the present invention. For example, a mapping where the least significant bits in a data symbol correspond to the largest area of coverage on the mapping constellation could be used. In this case, the least significant bit positions in the data symbol could be selectively punctured with signaling information since these positions would inherently have the highest LLRs due to their

coverage of the constellation. Further, the lesser significant and most significant bits could be punctured to yield gains in the LLRs of the least significant bits correlative to the puncturing of lesser and least significant bit positions of the Karnaugh mapped system described previously. Other mappings where other lesser significant bits or combinations of most, lesser or least significant bits represent the highest area of constellation coverage may also be envisioned.

Based on the foregoing, the degree of reliability for the signaling channel can be selectively set, dependent on the adaptive puncturing of particular bits in a data symbol and the number of those bits actually punctured. To achieve higher signaling reliability, those bit positions having the highest LLRs given a particular mapping scheme (e.g., those bit positions in a data symbol having the greatest constellation area coverage) can be chosen for puncturing with signaling information. However, the more bits punctured results in greater degradation to the high data rate QAM channel. Nonetheless, convolutional or Turbo encoding of the high data rate information is capable of protecting the information data bits against single-bit puncturing such that degradation is minimal. Additionally, the signaling bits themselves are easily decoded by signaling channel decoder 212 without incurring any Turbo or convolutional decoder delay.

In operation, the system of FIG. 2 effects a signaling channel by first determining a desired reliability level (i.e., the desired number of bits to be punctured in a data symbol). This selection, however, need not be static, but may be varied continuously dependent on the level of noise present in the system. Signaling bit encoder 206 selects particular data symbols to puncture periodically based on a predetermined time or any other criterion. Irrespective of the methodology for deciding

which data symbol or symbols of multiple data symbols are punctured, information concerning which data symbols are punctured is common to both the transmitter and receiver such that the receiver knows which data symbols it receives are punctured with signaling channel information. Preferably, the actual signaling information is contained in most significant bit b_5 and the selective reliability of the signaling channel is set by puncturing either bit b_3 or bits b_3 and b_1, but may be different for other alternate mapping schemes and symbol sequences. Once a data symbol is punctured by the signaling bit encoder 206, the punctured data symbol, along with non-punctured data symbols, are modulated by QAM mapper 204 according to the predetermined mapping scheme. Preferably this mapping scheme is a Gray-coded Karnaugh map as exemplified in FIG. 3. The modulated data symbols are then transmitted by an interface 208, such as a wireless interface, to a receiver.

Modulated data symbols are received by the receiver and are input to Symbol-to-LLR calculator 210. Symbol-to-LLR calculator 210 determines, for each bit of each received data symbol, the minimum squared Euclidean distance between a point in the complex plane corresponding to the received data symbol and each of a constellation point corresponding to a data symbol where the value of the bit is a "1" and a constellation point corresponding to a data symbol where the value of the bit is a "0". The difference of these minimum squared Euclidean distances yields the LLR. When a punctured data symbol is output by Symbol-to-LLR calculator 210 that is known by the receiver to be punctured according to the predetermined puncturing scheme, signaling channel decoder 212 simply reads the value of the computed LLR for the punctured bit (here bit b_5). If the LLR for the punctured is positive then the signaling bit is decoded

as a "0", for example. Conversely, if the LLR is negative then the signaling bit is decoded as a "1". It is noted that this could be alternatively be the opposite of the foregoing, dependent on the particular mapping scheme utilized. The punctured symbol is then input to zero-fill punctured bits inserter 214, which replaces the punctured bits within the punctured data symbol with a soft value of zero corresponding to an equal likelihood of a bit value of a "1" or a "0". The LLR values are then delivered to bit-wise decoder 216 that employs convolutional decoding, Turbo decoding or any other known decoding methodology known in the art to recover the data bits.

The puncturing scheme according to the teachings of the present invention may be applied to any other M-ary square constellation where M is an integer power of 2 and is also greater than 4. As noted previously, the constellation for the QAM mapping may employ some form of Karnaugh mapping as that illustrated in FIG. 3 but need not be identical to this mapping or may also employ a mapping that is not Karnaugh mapping or Gray-coded. With other M-ary square constellation QAM systems, the bit location or locations having the highest LLRs may be punctured with the signaling channel data. In addition, other bits that are known to affect the LLR of the bit locations having the highest LLRs may be punctured with particular binary values in order to obtain higher degrees of LLR gain.

The above teachings of the present invention may be utilized in any multiple-access communication system employing QAM with bit-wise decoders and a low data rate channel for signaling purposes. Use of the bit puncturing scheme according to the teachings of the present invention affords reliability and reduces latency for signaling bits in high data rate channels. Adaptive puncturing according to the teachings of the

present application affords also a simple solution that may be easily implemented in hardware and affords flexibility to adjust the reliability to support the minimum quality of service required. It will be further apparent to those skilled in the art that other embodiments other than the specific disclosed embodiments described above may be devised without departing from the fair scope of the appended claims and their equivalents.

What is claimed is:

1. An apparatus for providing adaptive signaling in a communication system, the apparatus having a transmitter comprising:

a signaling bit encoder configured to selectively puncture, based on a log-likelihood ratio, one or more bits of a data symbol comprised of a plurality of bits with at least one signaling bit representing signaling information to achieve a punctured data symbol; and

a mapper configured to modulate the punctured data symbol according to a predetermined mapping scheme having predetermined characteristics, the transmitter configured to transmit the modulated punctured data symbol.

2. The apparatus according to claim 1, wherein the transmitter selectively punctures one or more bits of the data symbol with the at least one signaling bit that have a highest inherent log-likelihood ratio among all bits in the data symbol.

3. The apparatus according to claim 1, wherein the signaling bit encoder selectively punctures a most significant odd bit position of a data symbol with the at least one signaling bit and adaptively punctures one of one or more lesser significant odd bits in the data symbol or a combination of lesser significant odd bits and a least significant odd bit with predetermined bit values to achieve a prescribed log-likelihood ratio gain for the most significant odd bit position.

4. The apparatus according to claim 1, wherein the signaling bit encoder selectively punctures a most significant even bit position of a data symbol with the at least one signaling bit and adaptively punctures one of one or more lesser significant even bits in the data symbol or a combination of lesser significant even bits and a least significant even bit with predetermined bit values to achieve a prescribed log-likelihood ratio gain for the most significant even bit position.

5. A receiver configured for receiving, decoding and demodulating a data symbol encoded by a transmitter, which transmitter selectively punctures one or more bit locations of the data symbol comprised of a plurality of bits with at least one signaling bit representing signaling information to achieve a punctured data symbol and modulates the punctured data symbol according to a predetermined mapping scheme having predetermined characteristics, the transmitter configured to transmit the modulated punctured data symbol to the receiver, wherein the receiver comprises:

a symbol-to-log-likelihood ratio calculator configured to receive the transmitted punctured data symbol and calculate a log-likelihood ratio for each bit of the received punctured data symbol; and

a signaling channel decoder configured to extract the signaling information from the at least one signaling bit in the punctured data symbol based on the calculated log-likelihood ratio of the at least one signaling bit.

6. The receiver according to claim 5, wherein the signaling channel decoder is configured to extract signaling information within the punctured bit by determining a

sign of the log-likelihood ratio calculated by the symbol-to-log-likelihood ratio calculator for a bit location into which the at least one signaling bit has been punctured.

7. The receiver according to claim 6, wherein the signaling channel decoder assigns the at least one signaling bit a first binary value when the sign of the calculated log-likelihood ratio is negative and assigns the at least one signaling bit a second binary value when the sign of the calculated log-likelihood ratio is positive.

8. The receiver according to claim 5, further comprising a zero-fill inserter receiving an output of the symbol-to-log-likelihood calculator and configured to insert a soft value of zero into data symbol bit locations punctured by the transmitter.

9. A method for providing signaling in a communication system comprising steps of:

puncturing one or more particular bits of a data symbol comprised of a plurality of bits with at least one signaling bit representing signaling information to achieve a punctured data symbol, wherein the puncturing is based on a log-likelihood ratio;

modulating the punctured data symbol according to a predetermined mapping scheme having predetermined characteristics; and

transmitting the modulated punctured data symbol.

10. The method according to claim 9, wherein bit locations within a data symbol that have a highest inherent log-likelihood ratio are punctured with the signaling information.

11. The method according to claim 9, wherein a most significant odd bit position of a data symbol is selectively punctured with the at least one signaling bit and one of one or more lesser significant odd bits in the data symbol or a combination of lesser significant odd bits and a least significant odd bit with predetermined bit values are adaptively punctured to achieve a prescribed log-likelihood ratio gain for the most significant odd bit position.

12. The method according to claim 9, wherein a most significant even bit position of a data symbol is selectively punctured with the at least one signaling bit and one of one or more lesser significant even bits in the data symbol or a combination of lesser significant even bits and a least significant even bit with predetermined bit values are adaptively punctured to achieve a prescribed log-likelihood ratio gain for the most significant even bit position.

13. A method for receiving data, wherein one or more particular bits of a data symbol comprised of a plurality of bits are punctured with one or more signaling bits representing signaling information to achieve a punctured data symbol, wherein the punctured data symbol is modulated according to a predetermined mapping scheme

having predetermined characteristics to produce a modulated data symbol, and wherein the method comprises steps of:

receiving the modulated data symbol;

demodulating the modulated data symbol by calculating the log-likelihood ratio for each bit of the punctured data symbol based on the predetermined mapping scheme; and

decoding the signaling bits within the demodulated data symbol.

14. The method according to claim 13, wherein signaling information within the punctured bit is extracted by determining a sign of the log-likelihood ratio calculated for a bit location into which the at least one signaling bit has been punctured.

15. The method according to claim 14, wherein the at least one signaling bit is assigned a first binary value when the sign of the calculated log-likelihood ratio is negative and the at least one signaling bit is assigned a second binary value when the sign of the calculated log-likelihood ratio is positive.

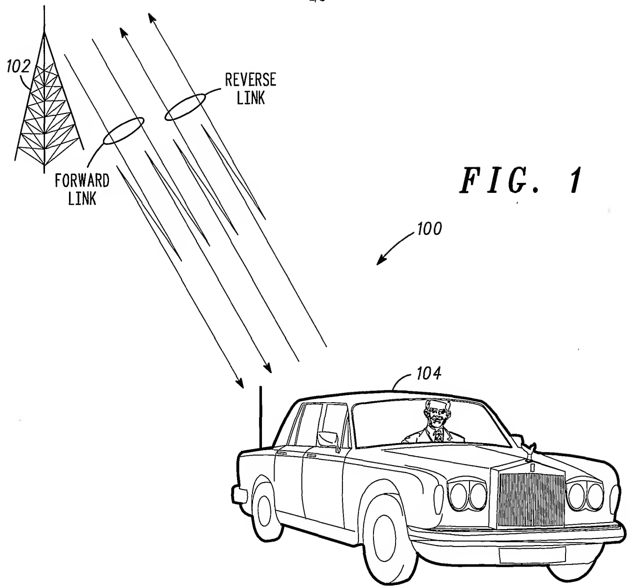
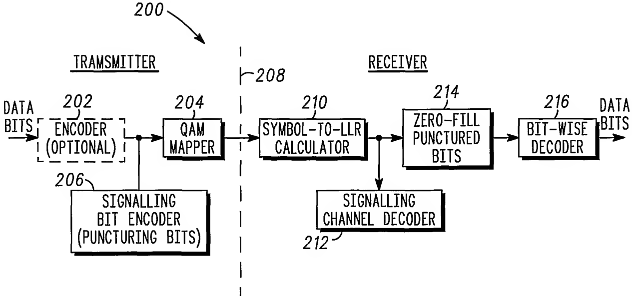
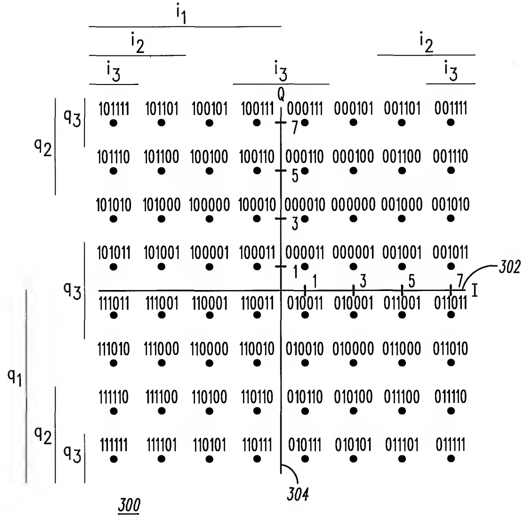

102
REVERSE LINK
FORWARD LINK
100
104

FIG. 1

FIG. 2


200
TRAMSMITTER
RECEIVER
208
DATA BITS
202
ENCODER (OPTIONAL)
204
QAM MAPPER
210
SYMBOL-TO-LLR CALCULATOR
214
ZERO-FILL PUNCTURED BITS
216
BIT-WISE DECODER
DATA BITS
206
SIGNALLING BIT ENCODER (PUNCTURING BITS)
SIGNALLING CHANNEL DECODER
212


i1
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101110 101100 100100 100110 000110 000100 001100 001110
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111011 111001 110001 110011 010011 010001 011001 011011
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111110 111100 110100 110110 010110 010100 011100 011110
111111 111101 110101 110111 010111 010101 011101 011111
7
5
3
1
1
3
5
7
I
302
304
300

FIG. 3

BIT POSITION	DEPENDENCY ON OTHER BITS	LLR
BIT b_0	NONE	$\pm 4D^2$
BIT b_1	NONE	$\pm 4D^2$
BIT b_2	BIT b_0=1	$\pm 16D^2$
	BIT b_0=0	$\pm 4D^2$
BIT b_3	BIT b_1=1	$\pm 16D^2$
	BIT b_1=0	$\pm 4D^2$
BIT b_4	BIT b_2=1, BIT b_0=1	$\pm 64D^2$
	BIT b_2=1, BIT b_0=0	$\pm 36D^2$
	BIT b_2=0, BIT b_0=0	$\pm 16D^2$
	BIT b_2=0, BIT b_0=1	$\pm 4D^2$
BIT b_5	BIT b_3=1, BIT b_1=1	$\pm 64D^2$
	BIT b_3=1, BIT b_1=0	$\pm 36D^2$
	BIT b_3=0, BIT b_1=0	$\pm 16D^2$
	BIT b_3=0, BIT b_1=1	$\pm 4D^2$

FIG. 4

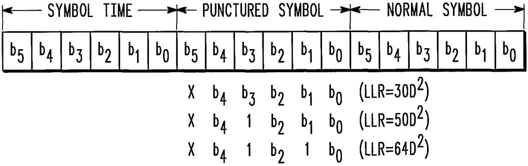

FIG. 5

International Application No
PCT/US 02/15889

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H03M H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	SUNYOUNG KIM ET AL: "An improved scheme in CDMA forward link using unequal error protection" UNIVERSAL PERSONAL COMMUNICATIONS, 1998. ICUPC '98. IEEE 1998 INTERNATIONAL CONFERENCE ON FLORENCE, ITALY 5-9 OCT. 1998, NEW YORK, NY, USA,IEEE, US, 5 October 1998 (1998-10-05), pages 1093-1096, XP010315001 ISBN: 0-7803-5106-1 page 1093, right-hand column, line 22 - line 32 page 1095, left-hand column, line 11 - line 15 page 1095, left-hand column, line 21 - line 39 figures 2-4; table 2 --- -/--	1,5,9,13

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 October 2002	08/11/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Papantoniou, A

2

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/15889

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 1 050 989 A (TEXAS INSTRUMENTS INC) 8 November 2000 (2000-11-08) page 3, line 50 - line 55 page 4, line 3 - line 9 page 8, line 5 - line 15 page 9, line 34 - line 35 figure 3 ---	1,5,9,13
A	EP 0 624 019 A (GEN INSTRUMENT CORP) 9 November 1994 (1994-11-09) page 3, line 32 - line 35 page 5, line 29 - line 34 page 7, line 37 - line 46 figure 1 -----	1,5,9,13

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 02/15889

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		EP 0624019 A2	09-11-1994
		JP 8051464 A	20-02-1996
		NO 941641 A	07-11-1994

(12) NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT) VERÖFFENTLICHTE INTERNATIONALE ANMELDUNG

(19) Weltorganisation für geistiges Eigentum
Internationales Büro

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102 05 910.1 13. Februar 2002 (13.02.2002) DE

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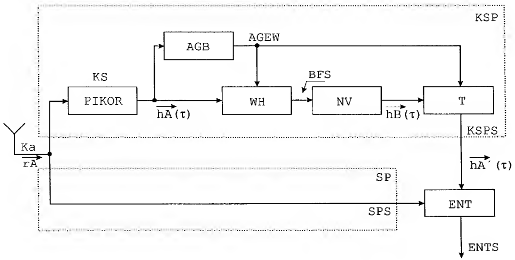
(81) Bestimmungsstaaten *(national)*: CN, JP, US.

(84) Bestimmungsstaaten *(regional)*: europäisches Patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR).

[Fortsetzung auf der nächsten Seite]

(54) Title: METHOD FOR BEAMFORMING A MULTI-USE RECEIVER WITH CHANNEL ESTIMATION

(54) Bezeichnung: METHODE ZUM BEAMFORMING EINES MEHRNUTZEMPFÄNGERS MIT KANALSCHÄTZUNG



(57) Abstract: The invention relates to a beamforming method for a multi-use receiver with an array of antennas. A covariance matrix and the eigenvalues thereof are determined following a channel estimation, from which antenna weights (AGEW) are calculated by means of a selection (AUS). A beamforming signal (BFS) is then obtained from the antenna weights and the channel estimations. Corrected channel estimations, which are used in a maximum ratio combining method, a zero forcing method, or a joint detection method (JDET) for estimating data, are then determined in a transformation stage (T). UTRA-TDD and UTRA-FDD transmission systems are examples of applications of the inventive method.

[Fortsetzung auf der nächsten Seite]

WO 03/069832 A1

Erklärungen gemäß Regel 4.17:

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— *Erfindererklärung (Regel 4.17 Ziffer iv) nur für US*

Veröffentlicht:

— *mit internationalem Recherchenbericht*

Zur Erklärung der Zweibuchstaben-Codes und der anderen Abkürzungen wird auf die Erklärungen ("Guidance Notes on Codes and Abbreviations") am Anfang jeder regulären Ausgabe der PCT-Gazette verwiesen.

(57) Zusammenfassung: Die Erfindung betrifft ein Beamforming-Verfahren für einen Mehrnutzempfänger mit Antennenarray. Nach einer Kanalschätzung werden eine Kovarianzmatrix und deren Eigenwerte bestimmt, woraus durch eine Auswahl (AUS) Antennengewichte (AGEW) berechnet werden. Aus den Antennen-gewichten und den Kanalschätzunger wird dann ein Beamformingsignal (BFS) gewonnen. In einer Transformationstufe (T) werden dann korrigierte Kanalschätzungen bestimmt, die in einem Maximum-Ratio-Combining-Verfahren, Zero-Forcing-Verfahren oder einem Joint-Detection-Verfahren (JDET) zur Datenschätzung verwendet werden. Anwendungsbeispiele sind UTRA-TDD und UTRA-FDD-Übertragungssysteme.

METHODE ZUM BEAMFORMING EINES MEHRNUTZEMPFÄNGERS MIT KANALSCHÄTZUNG

Beschreibung

Verfahren zur Bildung eines einer Kanaldecodierung zugeführten skalaren Entscheidungssignals, das mit Hilfe einer Kanalschätzung und eines Beamforming-Verfahrens aus Antennensignalen eines Funkkommunikationssystems gewonnenen wird.

Die Erfindung betrifft ein Verfahren gemäß den Merkmalen des ersten Patentanspruchs.

Bei Funkkommunikationssystemen mit mehreren Nutzern wird zur Empfangsverbesserung ein aus mehreren Einzelantennen bestehendes Antennensystem in Kombination mit einem sogenannten Mehrantennen-Empfänger eingesetzt. Über die Einzelantennen werden Antennensignale der Einzelantennen an den Mehrantennen-Empfänger weitergeleitet.

Durch die Verwendung von mehreren Einzelantennen, bzw. durch den dadurch entstehenden Kohärenzgewinn innerhalb des Mehrantennen-Empfängers, ist es möglich, niedrigere Signal-Störabstande bei den Antennensignalen für systembedingt vorgegebene Qualitätsanforderungen zuzulassen. Jedoch sind diese Antennensignale für ein durchzuführendes Kanalschätzungs-Verfahren bzw. für ein durchzuführendes Beamforming-Verfahren nur bedingt geeignet, da die durch Rauschen gestörten Antennensignale bei beiden Verfahren ungenaue Ergebnisse verursachen.

Bei bekannten Mehrantennen-Empfängern ist das Beamforming-Verfahren im sogenannten Signalpfad angeordnet, auf dem hohe Datenraten vorherrschen, während die Kanalschätzung in einem Kanalschätzpfad erfolgt. Sowohl Ausgangssignale des Kanalschätzpfads als auch des Signalpfads werden zur Bildung eines

skalaren Entscheidungssignals verwendet, das einer Kanaldecodierung bzw. einer Bitentscheidung zugeführt wird und funktionsbestimmend für den Mehrantennen-Empfänger ist.

Eine derartige Struktur ist beispielsweise auch beim sogenannten Einzelantennen-Empfänger realisierbar, der jedoch innerhalb eines betriebenen Funkkommunikationssystems im allgemeinen aus hardware- und softwarespezifischen Gründen nicht ohne weiteres zu einem Mehrantennen-Empfänger erweitert werden kann.

Die Aufgabe der vorliegenden Erfindung besteht darin, eine Empfängerstruktur zur Bildung eines skalaren Entscheidungssignals derart zu gestalten, dass die Empfängerstruktur sowohl in einem Mehrantennen-Empfänger als auch in einem Einzelantennen-Empfänger einsetzbar ist und der Einzelantennenempfänger nachträglich mit nur geringem Aufwand zu einem Mehrantennen-Empfänger erweiterbar ist.

Die Aufgabe der Erfindung wird durch die Merkmale des Anspruchs 1 gelöst. Vorteilhafte Weiterbildungen der Erfindung sind in den Unteransprüchen angegeben.

Durch die erfindungsgemäße Verlagerung des Beamforming-Verfahrens in den Kanalschätzpfad, in dem niedrigere Datenraten vorherrschen, wird eine nachträgliche Erweiterung eines Einzelantennen-Empfängers zu einem Mehrantennenempfänger auf einfache Art ermöglicht, denn:

- die Funktionen des Kanalschätzpfads werden mit Hilfe von digitalen Bausteinen realisiert und sind somit jederzeit leicht nachjustierbar bzw. erweiterbar, und

- im Erweiterungsfall wird zur Bildung des Entscheidungssignals nur noch die Hardware des Signalpfads entsprechend angepasst.

Die für das Beamforming-Verfahren erforderliche Rechenzeit wird ebenfalls reduziert, da im Kanalschätzpfad, verglichen mit dem Signalpfad, niedrigere Datenraten zu bearbeiten sind.

Vergleichend zum Stand der Technik, bei dem im allgemeinen zwei Pilotkorrelationen bzw. zwei Kanalschätzungen durchgeführt werden, ist beim erfindungsgemäßen Verfahren nur eine Kanalschätzung bzw. nur eine Pilotkorrelation zur Bildung des Entscheidungssignals notwendig.

Durch das erfindungsgemäße Verfahren werden die durch Rauschen ungenauen Kanalschätzungen, die auf den einzelnen Antennensignalen basieren, verbessert und es werden Langzeiteigenschaften des Kanals bei der Kanalschätzung vorteilhaft ausgenutzt.

Im Folgenden wird ein Ausführungsbeispiel der Erfindung anhand einer Zeichnung näher erläutert. Dabei zeigt:

FIG 1 als prinzipielles Schaltbild ein Verfahren zur Bildung eines skalaren Entscheidungssignals ENTS bei einem Mehrantennenempfänger, gemäß dem Stand der Technik,

FIG 2 als prinzipielles Schaltbild ein weiteres Verfahren zur Bildung eines skalaren Entscheidungssignals ENTS bei einem Mehrantennenempfänger, gemäß dem Stand der Technik,

FIG 3 als prinzipielles Schaltbild ein erfindungsgemäßes Verfahren zur Bildung eines skalaren Entscheidungssignals ENTS bei einem Mehrantennenempfänger,

FIG 4 vergleichend zu FIG 3 ein erstes Ausführungsbeispiel des erfindungsgemäßen Verfahrens zur Bildung eines skalaren Entscheidungssignals ENTS bei einem Mehrantennenempfänger, und

FIG 5 vergleichend zu FIG 3 ein zweites Ausführungsbeispiel des erfindungsgemäßen Verfahrens zur Bildung eines skalaren Entscheidungssignals ENTS bei einem Mehrantennenempfänger.

FIG 1 zeigt als prinzipielles Schaltbild ein Verfahren zur Bildung eines skalaren Entscheidungssignals ENTS bei einem Mehrantennenempfänger, gemäß dem Stand der Technik.

Es werden Ka Antennensignale von Ka Einzelantennen einer Antennenanordnung empfangen. Diese gelangen einerseits über einen Pilotkorrelator PIKOR und über eine nachfolgend angeordnete Nachverarbeitung NV und andererseits direkt an eine Einrichtung ENT, mit deren Hilfe das Entscheidungssignal ENTS gebildet wird. Das Entscheidungssignal ENTS wird dabei für jeden Nutzer des Funkkommunikationssystems gebildet und ist somit sowohl kanalspezifisch als auch nutzerspezifisch.

Mit dem Pilotkorrelator PIKOR und mit der Nachverarbeitung NV wird eine Kanalschätzung KS durchgeführt, mit deren Hilfe Kanalimpulsantworten hK als kanalspezifische Parameter ermittelt werden.
Bei der Nachverarbeitung NV werden beispielsweise anhand einer Schwellenentscheidung störende Rauschanteile bei den Ausgangssignalen des Pilotkorrelators PIKOR entfernt.

Zur Bildung des Entscheidungssignals ENTS werden die Ka Antennesignale mit Hilfe der Kanalimpulsantworten hK miteinander kombiniert bzw. adaptiv gefiltert. Realisiert wird dies

beispielsweise je nach Ausbildung des Funkkommunikationssystems durch ein „Maximum-Ratio-Combining"-Verfahren, „Joint-Detection"-Verfahren, den Einsatz eines „Wiener"-Filters oder durch ein „Zero-Forcing"-Verfahren. Dabei wird eine gemeinsame Detektion mehrerer Nutzer sowohl in Raum-, Zeit- als auch in Nutzerrichtung ermöglicht.

Derartige Verfahren werden bevorzugt bei TDD-Funkkommunikationssystemen eingesetzt, während der Einsatz bei FDD-Funkkommunikationssystemen nur mit großem Rechenaufwand realisiert werden kann.

Bei der Verwendung einer aus mehreren Einzelantennen bestehenden Antennenanordnung werden durch den systembedingten Antennengewinn geringere Signal-Störabstände bei den empfangenen Ka Antennensignalen tolerierbar, jedoch werden die durchzuführende Kanalschätzung KS und die Bildung des Entscheidungssignals ENTS durch die im allgemeinen stark verrauschten Ka Antennensignale nachteilig gestört und damit ungenauer.

FIG 2 zeigt als prinzipielles Schaltbild ein weiteres Verfahren zur Bildung eines skalaren Entscheidungssignals ENTS bei einem Mehrantennenempfänger, gemäß dem Stand der Technik.

Vergleichend zu FIG 1 nutzt dieser Mehrantennenempfänger Langzeiteigenschaften eines Kanals aus. Es gelangen Ka Antennensignale von Ka Einzelantennen einer Antennenanordnung als Eingangssignale sowohl an einen Kanalschätzpfad KS als auch an einen Signalpfad S.

Die Eingangssignale des Kanalschätzpfads KS gelangen an einen ersten Pilotkorrelator PIKOR1, mit dessen Hilfe Antennenimpulsantworten hA berechnet werden. Aus den Antennenimpulsant-

worten hA werden mit Hilfe einer Antennengewichtsberechnung AGB nutzerspezifische Antennengewichte AGEW berechnet. Mit Hilfe des ersten Pilotkorrelators PIKOR1 und der Antennengewichtsberechnung AGB wird eine erste Kanalschätzung KS1 durchgeführt.

Die Eingangssignale des Signalpfad S gelangen zusammen mit den berechneten Antennengewichten AGEW an einen im Signalpfad S angeordneten Beamformer WH, mit dessen Hilfe Beamsignale rB berechnet werden. Die Beamsignale rB gelangen einerseits als Ausgangssignale SA des Signalpfades S an eine Einrichtung ENT1, mit deren Hilfe das Entscheidungssignal ENTS gebildet wird, und andererseits an einen zweiten Pilotkorrelator PIKOR2. Ausgangssignale des zweiten Pilotkorrelators PIKOR2 gelangen nach einer Nachverarbeitung NV als Beamimpulssignale hB als Ausgangssignale KSA des Kanalschätzpfads KS ebenfalls an die Einrichtung ENT1. Mit Hilfe des zweiten Pilotkorrelators PIKOR2 und der Nachverarbeitung NV wird eine zweite Kanalschätzung KS2 durchgeführt.

Vergleichend mit FIG 1 werden zwei Kanalschätzungen KS1 und KS2 durchgeführt, wobei die aus FIG 1 bekannte Struktur in der Anordnung des ersten Pilotkorrelators PIKOR1, der Nachverarbeitung NV und des Beamformers WH zu sehen ist.

Mit Hilfe der ersten Kanalschätzung KS1 werden schnelle Fading-Eigenschaften der Kanäle gemittelt und Langzeiteigenschaften der Kanäle ausgenutzt. Die Beamsignale rB zeichnen sich durch einen höheren Signal-Störabstand aus. Bei der Bildung des Entscheidungssignals ENTS werden Kurzzeiteigenschaften des Kanals berücksichtigt.

Als mögliche Verfahren zur Antennengewichtsberechnung AGB sind Verfahren wie Eigen-Beamforming, Fixed-Beamforming, hybrides Beamforming sowie richtungsbasierende Verfahren bekannt. Die Antenenngewichte AGEW können trotz stark verrauschter Kanalschätzung auf den einzelnen Antennenelementen exakt bestimmt werden und stellen anschaulich einen oder mehrere Antennenbeams dar.

Die Bildung des Entscheidungssignals ENTS erfolgt beispielsweise wieder mit Hilfe eines Maximum-Ratio-Combining-Verfahrens oder eines Joint-Detection ähnlichen Verfahrens, wie beispielsweise dem Partial-Joint-Detection-Verfahren.

Bei diesem Mehrantennen-Empfänger ist als Nachteil zu nennen, dass die räumliche Signalverarbeitung weitgehend getrennt ist von der restlichen Signalverarbeitung.
Beim Joint-Detection-Verfahren, bei dem Raum, Zeit und Nutzer gemeinsam verarbeitet werden, ist eine derartige Empfängerstruktur im allgemeinen nicht anwendbar.
Das Beamforming WH erfolgt hier im Signalpfad, auf dem üblicherweise hohe Datenraten vorherrschen, wodurch erhöhte Rechenzeiten und Probleme bei der Hardware- bzw. Softwarerealisierung verursacht werden.

FIG 3 zeigt als prinzipielles Schaltbild ein erfindungsgemäßes Verfahren zur Bildung eines skalaren Entscheidungssignals ENTS bei einem Mehrantennenempfänger.

Es gelangen Ka Antennensignale von Ka Einzelantennen einer Antennenanordnung als Eingangssignale einerseits an einen Kanalschätzpfad KSP und anderseits an einen Signalpfad SP.
Die Eingangssignale des Kanalschätzpfades KSP werden einem Pilotkorrelator PIKOR zugeführt, mit dessen Hilfe eine Kanal-

schätzung KS durchgeführt wird und nutzerspezifische Antennenimpulsantworten hA gebildet werden. Mit Hilfe der nutzerspezifischen Antennenimpulsantworten hA wird eine Antennengewichtsberechnung AGB zur Bestimmung von Antennenngewichten AGEW durchgeführt.

Mit Hilfe der berechneten Antennengewichte AGEW und der Antennenimpulsantworten hA wird ein Beamforming WH durchgeführt, dessen Ausgangssignale als Beamformingsignale BFS einer Nachverarbeitung NV zugeführt werden. Mit Hilfe der Nachverarbeitung NV werden Beamimpulsantworten hB gebildet, die an einen Transformator T gelangen.

Der Transformator T dient der Rücktransformation der Beamimpulsantworten hB in den Antennenbereich und bildet mit Hilfe der Beamimpulssignale hB und der berechneten Antennengewichte AGEW korrigierte nutzerspezifische Impulsantworten hA´, die als Ausgangssignale KSPS des Kanalschätzpfads KSP den Antennenimpulsantworten hA nachgebildet sind.

Sowohl die Ka Antennensignale des Signalpfads als auch die korrigierten Impulsantworten hA´ werden einer Einrichtung ENT zur Bildung des Entscheidungssignals ENTS zugeführt.
Die Bildung des Entscheidungssignals ENTS erfolgt mit Hilfe von adaptiven Filter-Kombinierungsfunktionen, je nach Ausbildung des Funkkommunikationssystems beispielsweise durch ein „Maximum-Ratio-Combining"-Verfahren, „Joint-Detection"-Verfahren, dem Einsatz eines „Wiener"-Filters oder durch ein „Zero-Forcing"-Verfahren.

Vergleichend zur FIG 2 ist das Beamforming WH aus dem Signalpfad SP in den Kanalschätzpfand KSP verlagert worden, wobei

bei dem erfindungsgemäßen Verfahren nur noch eine Pilotkorrelation PIKOR durchgeführt wird.

Da innerhalb des Kanalschätzpfades KSP vergleichend zum Signalpfad SP geringere Datenraten auftreten, ist ein derartiger Mehrantennen-Empfänger leicht zu realisieren bzw. zu erweitern.

Erfindungsgemäß werden die berechneten Antennengewichte AGEW sowie die Transformation T jeweils auf die gesamten Antennenimpulsantworten hA, also auf jeden einzelnen Wert, angewendet.

Alternativ sind dazu bei der Antennegewichtsberechnung AGB folgende Erweiterungen möglich:

a.) Für jeden einzelnen Wert der Antennenimpulsantwort hA wird ein eigenes Set an Antennengewichtsfaktoren AGEW und eine Transformation T berechnet, die dann jeweils nur auf den jeweiligen Wert angewendet werden.

b.) Die Werte der Antennenimpulsantworten werden gruppiert und für jede einzelne Gruppe wird ein Set von Antennengewichten und eine Transformation T berechnet, die dann jeweils auf jeden Wert dieser Gruppe angewendet werden.

Erfindungsgemäß können anstelle der linearen adaptiven Filter-Kombinierungsfunktionen bei der Bildung des Entscheidungssignals auch grundsätzlich nicht lineare Strukturen wie „Decision-Feedback" oder „Interference-Cancellation" usw. verwendet werden. Diese sind im allgemeinen mehrstufig und werden durch das erfindungsgemäße Verfahren ebenfalls verbessert, indem der Kanalschätzpfad jeder Stufe mit der beschriebenen Struktur entsprechend erweitert wird.

FIG 4 zeigt vergleichend zu FIG 3 ein erstes Ausführungsbeispiel des erfindungsgemäßen Verfahrens zur Bildung eines skalaren Entscheidungssignals ENTS bei einem Mehrantennenempfänger. Dabei wird ein UTRA-FDD-Funkkommunikationssystem vorausgesetzt.

Die Ka Antennesignale gelangen an einen Delay-Seacher DELS, mit dessen Hilfe der Pilotkorrelator DESP des Kanalschätzpfades KSP nutzerspezifische DPCCH-Kanäle entspreizt und Antennenimpulsantworten hA erzeugt, die einerseits zur Antennengewichtsberechnung AGB und andererseits zum Beamforming WH verwendet werden. Dabei beinhaltet jede einzelne nutzerspezifische Antennenimpulsantwort Kt*Ka Antennenkoeffizienten, wobei Kt mit Hilfe des Delay-Searchers DELS lagenabhängig von Energiemaxima bestimmt wird.

Die Antennengewichtsberechnung AGB erfolgt dabei mit Hilfe von Kovarianzmatrixschätzungen COV, Eigenwertzerlegungen EVD und einem Auswahlverfahren AUS. Die berechneten Antennengewichte AGEW werden mit den Antennenimpulsantworten hA dem Beamformer WH zugeführt, dessen Ausgangssignale als Beamformingsignale BFS über eine hier nicht notwendige Nachverarbeitung NV als Beamimpulsantworten hB dem Transformator T zugeführt werden.
Die mit Hilfe des Transformators T gebildeten korrigierten Impulsantworten hA´ gelangen an die Einrichtung ENT zur Bildung des Entscheidungssignals ENTS, das hier mit Hilfe eines Maximum-Ratio-Combiners MRC gebildet wird.

Bei den Eingangssignalen des Signalpfads SP werden mit Hilfe des Delay-Searchers DELS nutzerspezifische DPDCH-Kanäle entspreizt (DESP) und Kt*Ka Antennen-Delay-Signale berechnet,

die zusammen mit den korrigierten Impulsantworten hA´ zur Bildung des Entscheidungssignals ENTS verwendet werden.

FIG 5 zeigt vergleichend zu FIG 3 ein zweites Ausführungsbeispiel des erfindungsgemäßen Verfahrens zur Bildung eines skalaren Entscheidungssignals ENTS bei einem Mehrantennenempfänger. Dabei wird ein UTRA-TDD-Funkkommunikationssystem vorausgesetzt.

Die Pilotkorrelation PIKOR erfolgt hier mit Hilfe einer Midambelkorrelation MIDCO. Die Antennengewichtsberechnung AGB erfolgt wieder mit Hilfe von Kovarianzmatrixschätzungen COV, Eigenwertzerlegungen EVD und einem Auswahlverfahren AUS. Mit Hilfe des Auswahlverfahrens AUS werden beispielsweise nur maximale Leistungen von Nutzern weiterverfolgt.

Die Nachverarbeitung NV bildet ein Schwellenentscheider SCH, während die Bildung des Entscheidungssignals ENTS mit Hilfe eines Joint-Detectors JDET erfolgt.

Auf jedes der Ka Antennensignale werden für jeden einzelnen von Ku Nutzern durch Midamblekorrelation insgesamt Ku*Ka Antennenimpulsantworten hA ermittelt, für die anschließend für jeden einzelnen Nutzer eine Kovarianzmatrix geschätzt wird. Eine geeignete Untermenge an Eigenwerten jeder Kovarianzmatrix wird zunächst als Transformation auf die zugehörige Impulsantwort angewendet.

Die Schwellenentscheidung SCH setzt anschließend kleine Werte der Impulsantwort, die in der Regel nur Rauschanteile darstellen, auf den Wert Null. Mit Hilfe der Transformation T wird schließlich eine stark verbesserte Kanalschätzung er-

reicht. Der Joint-Detector JDET an sich wird herkömmlich, jedoch mit weniger verrauschten Impulsantworten, betrieben.

Patentansprüche

1. Verfahren zur Bildung eines einer Kanaldecodierung zugeführten skalaren Entscheidungssignals (ENTS), das mit Hilfe einer Kanalschätzung (KS) und mit Hilfe eines Beamforming-Verfahrens (WH) aus Ka Antennensignalen eines Funkkommunikationssystems gewonnen wird,
   - bei dem die Ka Antennensignale von Ka Einzelantennen als Eingangssignale sowohl an einen Kanalschätzpfad (KSP) als auch an einen dazu parallelen Signalpfad (SP) zur Bildung eines jeweiligen Ausgangssignals (KSPS,SPS) gelangen,
   - bei dem im Kanalschätzpfad (KSP) zur Bildung des Ausgangssignals (KSPS) an den Ka Antennensignalen zunächst die Kanalschätzung (KS) und nachfolgend das Beamforming-Verfahren (WH) durchgeführt wird, und
   - bei dem aus den Ausgangssignalen (KSPS,SPS) des Signalpfads (SP) und des Kanalschätzpfads (KSP) das skalare Entscheidungssignal (ENTS) gebildet wird.

2. Verfahren nach Anspruch 1, bei dem das skalare Entscheidungssignal (ENTS) mit Hilfe einer adaptiven Filter-Kombinierungsfunktion gebildet wird.

3. Verfahren nach Anspruch 1 oder 2, bei dem im Kanalschätzpfad (KSP) mit Hilfe eines Pilotkorrelationsverfahrens (PIKOR) aus den Ka Antennensignalen nutzerspezifische Antennenimpulsantworten (hA) gebildet werden, die einerseits zur Berechnung von nutzerspezifischen Antennengewichten (AGEW) und andererseits zur Durchführung des Beamforming-Verfahrens (WH) verwendet werden.

4. Verfahren nach Anspruch 3, bei dem die berechneten Antennengewichte (AGEW) einerseits zur Durchführung des Beamforming-Verfahrens (WH) verwendet und andererseits einer Transformation (T) unterzogen werden.

5. Verfahren nach Anspruch 3 oder 4, bei dem mit Hilfe des Beamforming-Verfahrens (WH) nutzerspezifische Beamformingsignale (BFS) gebildet werden, die nach einer Nachverarbeitung (NV) als Beamimpulsantworten (hB) der Transformation (T) zugeführt werden.

6. Verfahren nach Anspruch 4 oder 5, bei dem mit Hilfe der Transformation (T) aus den Beamimpulsantworten (hB) und aus den berechneten Antennengewichten (AGEW) nutzerspezifische, den Antennenimpulsantworten (hA) nachgebildete, korrigierte Impulsantworten (hA´) als Ausgangssignale (KSPS) des Kanalschätzpfads (KSP) erzeugt werden.

7. Verfahren nach einem der vorhergehenden Ansprüche, bei dem für Ku Nutzer die nutzerspezifischen Antennengewichte (AGEW) mit Hilfe von Kovarianzmatrix-Schätzungen (COV), Eigenwertzerlegungen (EVD) und einem Auswahlverfahren (AUS) bestimmt werden.

8. Verfahren nach einem der vorhergehenden Ansprüche, gekennzeichnet durch die Verwendung in einem UTRA-TDD-Funkkommunikationssystem.

9. Verfahren nach Anspruch 8, bei dem als Pilotkorrelationsverfahren (PIKOR) eine Midamble-Korrelation (MIDCO) zur Bildung von Ku*Ka Antennenimpulsantworten (hA) von Ku Nutzern verwendet wird.

10. Verfahren nach Anspruch 8 oder 9, bei dem die Nachverarbeitung (NV) der Beamformingsignale (BFS) mit Hilfe einer Schwellenentscheidung (SCH) erfolgt.

11. Verfahren nach einem der Ansprüche 8 bis 10, bei dem bei der Bildung des Entscheidungssignals (ENTS) als adaptive Filter-Kombinierungsfunktion ein Joint-Detection-Verfahren (JDET) verwendet wird, wobei Ku*Ka korrigierte Impulsantworten (hA´) einerseits und Ka Antennensignale andererseits die Ausgangssignale (KSPS,SPS) des Kanalschätzpfads (KSP) einerseits und des Signalpfads (SP) andererseits bilden.

12. Verfahren nach Anspruch 7, gekennzeichnet durch die Verwendung in einem UTRA-FDD-Funkkommunikationssystem.

13. Verfahren nach Anspruch 12, bei dem beim Pilotkorrelationsverfahren mit Hilfe eines Delay-Searchers (DELS), dem die Ka Antennensignale zugeführt sind, den Nutzern zugeordnete DPCCH-Kanäle entspreizt und Kt*Ka Koeffizienten von Kt Delays des Delay-Searchers als Antennenimpulsantworten (hA) gebildet werden.

14. Verfahren nach Anspruch 12 oder 13, bei dem die Nachverarbeitung (NV) der Beamformingsignale (BFS) derart erfolgt, dass diese als Beamimpulsantworten (hB) zur Transformation (T) gelangen.

15. Verfahren nach einem der Ansprüche 12 bis 14, bei dem bei der Bildung des Entscheidungssignals (ENTS) als adaptive Filter-Kombinierungsfunktion ein Maximum-Ratio-Combining-Verfahren (MRC) verwendet wird.

16. Verfahren nach einem der Ansprüche 13 bis 15, bei dem im Signalpfad (SP) mit Hilfe des Delay-Searchers (DELS) aus den Eingangssignalen des Signalpfades nutzerspezifische DPDCH-Kanäle entspreizt und Kt*Ka Antennen-Delay-Signale berechnet werden, die mit den korrigierten Impulsantworten (hA´) zur Bildung des Entscheidungssignals (ENTS) verwendet werden.

17. Verfahren nach einem der vorhergehenden Ansprüche, bei dem die Berechnung der Antennengewichte (AGEW) mit Hilfe eines Fixed-Beamforming-Verfahrens oder eines Eigenbeamforming-Verfahrens oder einer Kombination daraus erfolgt.

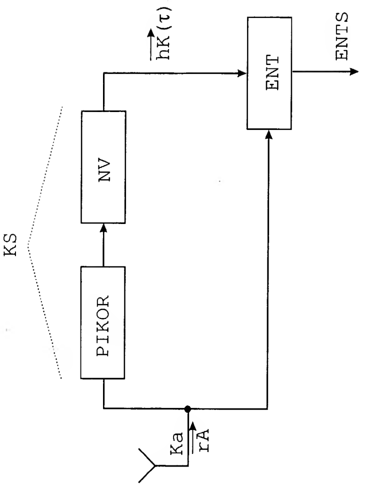

FIG 1

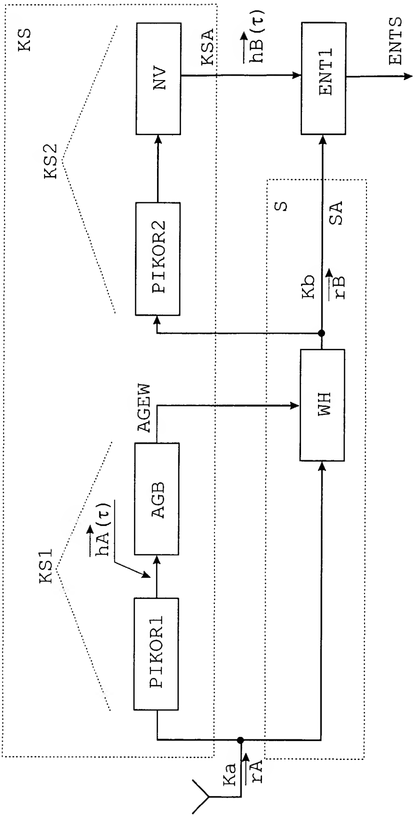
KS
KS1
KS2
PIKOR1
AGB
$\overrightarrow{hA}(\tau)$
AGEW
PIKOR2
NV
KSA
$\overrightarrow{hB}(\tau)$
ENT1
ENTS
S
WH
Kb
$\overrightarrow{rB}$
SA
Ka
$\overrightarrow{rA}$

FIG 2

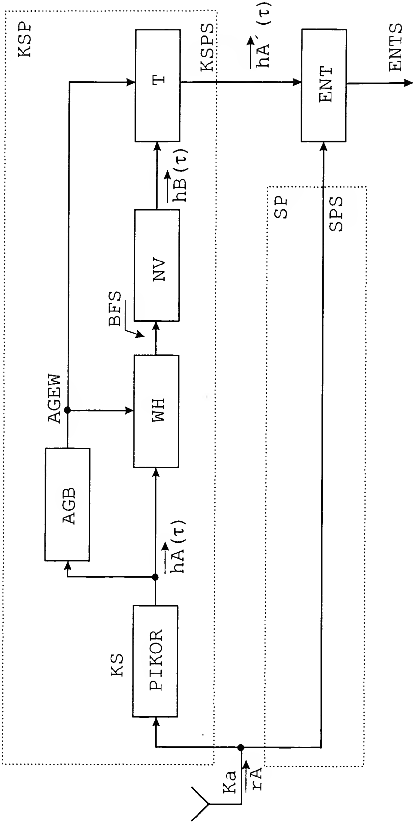
KSP
T
KSPS
hA´(τ)
ENT
ENTS
hB(τ)
SP
SPS
NV
BFS
AGEW
WH
AGB
hA(τ)
KS
PIKOR
Ka
rA

FIG 3

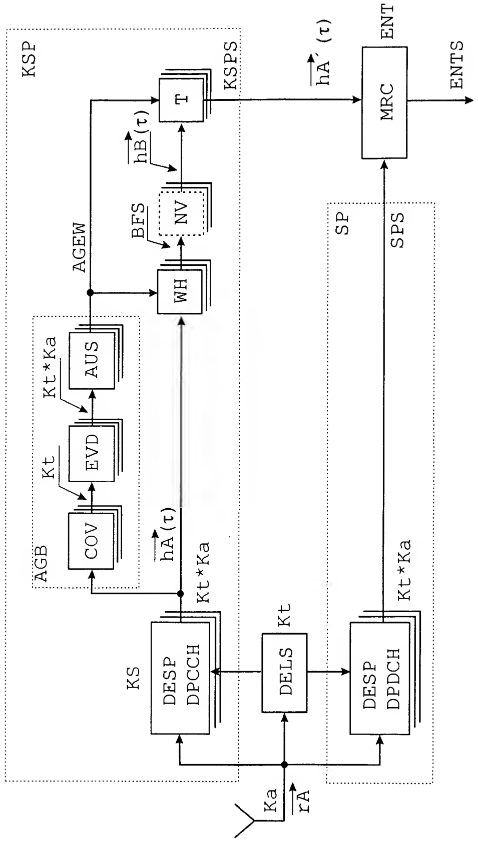
KSP
KSPS
T
hB(τ)
NV
BFS
WH
AGEW
AGB
COV
EVD
AUS
Kt
Kt*Ka
hA(τ)
Kt*Ka
KS
DESP DPCCH
DELS
Kt
DESP DPDCH
Kt*Ka
SP
SPS
MRC
ENT
ENTS
hA´(τ)
Ka
rA

FIG 4

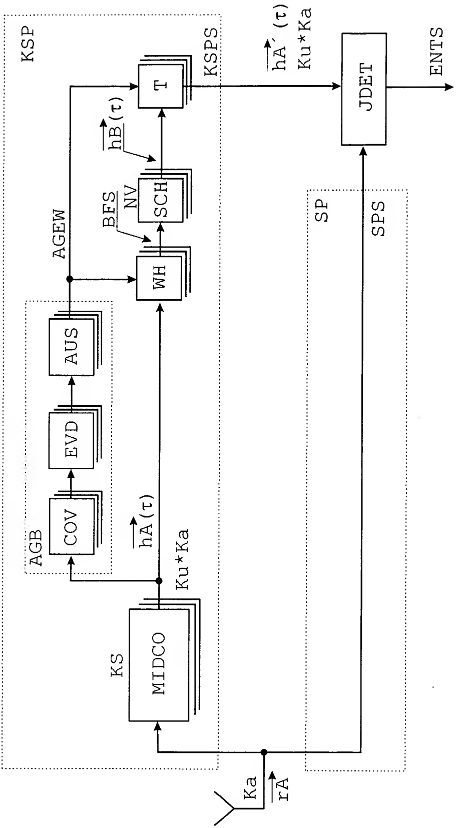
KSP
KSPS
T
$\overrightarrow{hA}'(\tau)$
Ku*Ka
JDET
ENTS
$\overrightarrow{hB}(\tau)$
BFS
NV
SCH
AGEW
WH
AUS
EVD
COV
AGB
$\overrightarrow{hA}(\tau)$
Ku*Ka
KS
MIDCO
SP
SPS
Ka
$\overrightarrow{rA}$

FIG 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/01043

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L1/06 H04B7/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

INSPEC, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 347 234 B1 (SCHERZER SHIMON B) 12 February 2002 (2002-02-12) figures 1,12,13 column 5, line 16 - line 19 column 7, paragraph 1 - paragraph 2 ---	1,8,9

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

11 April 2003

Date of mailing of the international search report

06/05/2003

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL – 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Stolte, N

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	JOONSUK KIM ET AL: "Spatial multiuser access with antenna diversity using singular value decomposition" 2000 IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS. ICC 2000. GLOBAL CONVERGENCE THROUGH COMMUNICATIONS. CONFERENCE RECORD, PROCEEDINGS OF IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS, NEW ORLEANS, LA, USA, 18-22 JUNE 2000, pages 1253-1257 vol.3, XP002204464 2000, Piscataway, NJ, USA, IEEE, USA ISBN: 0-7803-6283-7 figure 1 page 1253, column 2, last paragraph -page 1255, column 1, paragraph 4 ---	1,8,9
A	I-TAI LU ET AL: "Sensitivity study of smart antenna systems with both transmission and reception diversities" MILITARY COMMUNICATIONS CONFERENCE PROCEEDINGS, 1999. MILCOM 1999. IEEE ATLANTIC CITY, NJ, USA 31 OCT.-3 NOV. 1999, PISCATAWAY, NJ, USA,IEEE, US, 31 October 1999 (1999-10-31), pages 949-953, XP010369802 ISBN: 0-7803-5538-5 Abschnitt II ---	1
A	YIM C ET AL: "ADAPTIVE ARRAY ANTENNA BASED ON ESTIMATION OF ARRIVAL ANGLES USING DFT ON SPATIAL DOMAIN" ELECTRONICS & COMMUNICATIONS IN JAPAN, PART I - COMMUNICATIONS, SCRIPTA TECHNICA. NEW YORK, US, vol. 76, no. 8, 1 August 1993 (1993-08-01), pages 96-107, XP000428985 ISSN: 8756-6621 figure 1 page 98, column 2, paragraph 1 - paragraph 2 Abschnitt 3 --- -/--	1

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	THOMPSON J S ET AL: "PERFORMANCE OF ANTENNA ARRAY RECEIVER ALGORITHMS FOR CDMA" COMMUNICATIONS: THE KEY TO GLOBAL PROSPERITY. GLOBECOM 1996. LONDON, NOV. 18 - 22, 1996, GLOBAL TELECOMMUNICATIONS CONFERENCE (GLOBECOM), NEW YORK, IEEE, US, vol. 1, 18 November 1996 (1996-11-18), pages 570-574, XP000742212 ISBN: 0-7803-3337-3 page 571, column 1, paragraph 3 Abschnitt 2.2 Abschnitt 3 -----	1

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

Continuation of Box 1.2

Claims: 3-7, 10-17

The entire application does not contain sufficient information to permit the following steps of the claimed methods to be analysed in terms of their technical features:

1. Antenna weight determination, in particular the determination of the covariance matrix, the selection in the selection method and the determination of the antenna weights from the selected elements.
2. The beamforming method in the block WH.
3. The determination of the beamforming signal (BFS).
4. The transformation in the block T.
5. The use of the corrected impulse response for determining the decision signal.

Therefore, the application does not meet the requirements of PCT Article 5 since the invention has not been disclosed in a manner sufficiently clear and complete for it to be carried out by a person skilled in the art.

Therefore, the scope of protection of Claims 3-7 and 10-17 cannot be clearly determined, and for this reason it is impossible to carry out a meaningful search of the indicated claims.

The subjects of the aforementioned Claims 3-7 and 10-17 were therefore certainly not searched (PCT Article 17(2)(a)(ii)).

The applicant is advised that claims, or parts of claims, relating to inventions in respect of which no international search report has been established normally cannot be the subject of an international preliminary examination (PCT Rule 66.1(e)). In its capacity as International Preliminary Examining Authority the EPO generally will not carry out a preliminary examination for subjects that have not been searched. This also applies to cases where the claims were amended after receipt of the international search report (PCT Article 19) or where the applicant submits new claims in the course of the procedure under PCT Chapter II.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 03/01043

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6347234 B1	12-02-2002	US 6108565 A	22-08-2000
		US 6519478 B1	11-02-2003
		AU 9488598 A	05-04-1999
		BR 9812816 A	08-08-2000
		CA 2302547 A1	25-03-1999
		CN 1278971 T	03-01-2001
		EP 1062746 A2	27-12-2000
		NO 20001026 A	15-05-2000
		PL 339462 A1	18-12-2000
		WO 9914870 A2	25-03-1999

INTERNATIONALER RECHERCHENBERICHT

Internationales Aktenzeichen
PCT/EP 03/01043

A. KLASSIFIZIERUNG DES ANMELDUNGSGEGENSTANDES
IPK 7 H04L1/06 H04B7/08

Nach der Internationalen Patentklassifikation (IPK) oder nach der nationalen Klassifikation und der IPK

B. RECHERCHIERTE GEBIETE

Recherchierter Mindestprüfstoff (Klassifikationssystem und Klassifikationssymbole)
IPK 7 H04L H04B

Recherchierte aber nicht zum Mindestprüfstoff gehörende Veröffentlichungen, soweit diese unter die recherchierten Gebiete fallen

Während der internationalen Recherche konsultierte elektronische Datenbank (Name der Datenbank und evtl. verwendete Suchbegriffe)

INSPEC, EPO-Internal

C. ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie°	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
X	US 6 347 234 B1 (SCHERZER SHIMON B) 12. Februar 2002 (2002-02-12) Abbildungen 1,12,13 Spalte 5, Zeile 16 - Zeile 19 Spalte 7, Absatz 1 - Absatz 2 ---	1,8,9

-/--

[X] Weitere Veröffentlichungen sind der Fortsetzung von Feld C zu entnehmen

[X] Siehe Anhang Patentfamilie

° Besondere Kategorien von angegebenen Veröffentlichungen :

"A" Veröffentlichung, die den allgemeinen Stand der Technik definiert, aber nicht als besonders bedeutsam anzusehen ist

"E" älteres Dokument, das jedoch erst am oder nach dem internationalen Anmeldedatum veröffentlicht worden ist

"L" Veröffentlichung, die geeignet ist, einen Prioritätsanspruch zweifelhaft erscheinen zu lassen, oder durch die das Veröffentlichungsdatum einer anderen im Recherchenbericht genannten Veröffentlichung belegt werden soll oder die aus einem anderen besonderen Grund angegeben ist (wie ausgeführt)

"O" Veröffentlichung, die sich auf eine mündliche Offenbarung, eine Benutzung, eine Ausstellung oder andere Maßnahmen bezieht

"P" Veröffentlichung, die vor dem internationalen Anmeldedatum, aber nach dem beanspruchten Prioritätsdatum veröffentlicht worden ist

"T" Spätere Veröffentlichung, die nach dem internationalen Anmeldedatum oder dem Prioritätsdatum veröffentlicht worden ist und mit der Anmeldung nicht kollidiert, sondern nur zum Verständnis des der Erfindung zugrundeliegenden Prinzips oder der ihr zugrundeliegenden Theorie angegeben ist

"X" Veröffentlichung von besonderer Bedeutung; die beanspruchte Erfindung kann allein aufgrund dieser Veröffentlichung nicht als neu oder auf erfinderischer Tätigkeit beruhend betrachtet werden

"Y" Veröffentlichung von besonderer Bedeutung; die beanspruchte Erfindung kann nicht als auf erfinderischer Tätigkeit beruhend betrachtet werden, wenn die Veröffentlichung mit einer oder mehreren anderen Veröffentlichungen dieser Kategorie in Verbindung gebracht wird und diese Verbindung für einen Fachmann naheliegend ist

"&" Veröffentlichung, die Mitglied derselben Patentfamilie ist

Datum des Abschlusses der internationalen Recherche	Absendedatum des internationalen Recherchenberichts
11. April 2003	06/05/2003

Name und Postanschrift der Internationalen Recherchenbehörde	Bevollmächtigter Bediensteter
Europäisches Patentamt, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Stolte, N

C.(Fortsetzung) ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie°	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
X	JOONSUK KIM ET AL: "Spatial multiuser access with antenna diversity using singular value decomposition" 2000 IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS. ICC 2000. GLOBAL CONVERGENCE THROUGH COMMUNICATIONS. CONFERENCE RECORD, PROCEEDINGS OF IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS, NEW ORLEANS, LA, USA, 18-22 JUNE 2000, Seiten 1253-1257 vol.3, XP002204464 2000, Piscataway, NJ, USA, IEEE, USA ISBN: 0-7803-6283-7 Abbildung 1 Seite 1253, Spalte 2, letzter Absatz -Seite 1255, Spalte 1, Absatz 4 ---	1,8,9
A	I-TAI LU ET AL: "Sensitivity study of smart antenna systems with both transmission and reception diversities" MILITARY COMMUNICATIONS CONFERENCE PROCEEDINGS, 1999. MILCOM 1999. IEEE ATLANTIC CITY, NJ, USA 31 OCT.-3 NOV. 1999, PISCATAWAY, NJ, USA,IEEE, US, 31. Oktober 1999 (1999-10-31), Seiten 949-953, XP010369802 ISBN: 0-7803-5538-5 Abschnitt II ---	1
A	YIM C ET AL: "ADAPTIVE ARRAY ANTENNA BASED ON ESTIMATION OF ARRIVAL ANGLES USING DFT ON SPATIAL DOMAIN" ELECTRONICS & COMMUNICATIONS IN JAPAN, PART I - COMMUNICATIONS, SCRIPTA TECHNICA. NEW YORK, US, Bd. 76, Nr. 8, 1. August 1993 (1993-08-01), Seiten 96-107, XP000428985 ISSN: 8756-6621 Abbildung 1 Seite 98, Spalte 2, Absatz 1 - Absatz 2 Abschnitt 3 --- -/--	1

INTERNATIONALER RECHERCHENBERICHT

Internationales Aktenzeichen
PCT/EP 03/01043

C.(Fortsetzung) ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie°	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
A	THOMPSON J S ET AL: "PERFORMANCE OF ANTENNA ARRAY RECEIVER ALGORITHMS FOR CDMA" COMMUNICATIONS: THE KEY TO GLOBAL PROSPERITY. GLOBECOM 1996. LONDON, NOV. 18 - 22, 1996, GLOBAL TELECOMMUNICATIONS CONFERENCE (GLOBECOM), NEW YORK, IEEE, US, Bd. 1, 18. November 1996 (1996-11-18), Seiten 570-574, XP000742212 ISBN: 0-7803-3337-3 Seite 571, Spalte 1, Absatz 3 Abschnitt 2.2 Abschnitt 3 -----	1

INTERNATIONALER RECHERCHENBERICHT

Internationales Aktenzeichen
PCT/EP 03/01043

Feld I Bemerkungen zu den Ansprüchen, die sich als nicht recherchierbar erwiesen haben (Fortsetzung von Punkt 2 auf Blatt 1)

Gemäß Artikel 17(2)a) wurde aus folgenden Gründen für bestimmte Ansprüche kein Recherchenbericht erstellt:

1. ☐ Ansprüche Nr.
weil sie sich auf Gegenstände beziehen, zu deren Recherche die Behörde nicht verpflichtet ist, nämlich

2. ☒ Ansprüche Nr. 3-7, 10-17
weil sie sich auf Teile der internationalen Anmeldung beziehen, die den vorgeschriebenen Anforderungen so wenig entsprechen, daß eine sinnvolle internationale Recherche nicht durchgeführt werden kann, nämlich
siehe Zusatzblatt WEITERE ANGABEN PCT/ISA/210

3. ☐ Ansprüche Nr.
weil es sich dabei um abhängige Ansprüche handelt, die nicht entsprechend Satz 2 und 3 der Regel 6.4 a) abgefaßt sind.

Feld II Bemerkungen bei mangelnder Einheitlichkeit der Erfindung (Fortsetzung von Punkt 3 auf Blatt 1)

Die internationale Recherchenbehörde hat festgestellt, daß diese internationale Anmeldung mehrere Erfindungen enthält:

1. ☐ Da der Anmelder alle erforderlichen zusätzlichen Recherchengebühren rechtzeitig entrichtet hat, erstreckt sich dieser internationale Recherchenbericht auf alle recherchierbaren Ansprüche.

2. ☐ Da für alle recherchierbaren Ansprüche die Recherche ohne einen Arbeitsaufwand durchgeführt werden konnte, der eine zusätzliche Recherchengebühr gerechtfertigt hätte, hat die Behörde nicht zur Zahlung einer solchen Gebühr aufgefordert.

3. ☐ Da der Anmelder nur einige der erforderlichen zusätzlichen Recherchengebühren rechtzeitig entrichtet hat, erstreckt sich dieser internationale Recherchenbericht nur auf die Ansprüche, für die Gebühren entrichtet worden sind, nämlich auf die Ansprüche Nr.

4. ☐ Der Anmelder hat die erforderlichen zusätzlichen Recherchengebühren nicht rechtzeitig entrichtet. Der internationale Recherchenbericht beschränkt sich daher auf die in den Ansprüchen zuerst erwähnte Erfindung; diese ist in folgenden Ansprüchen erfaßt:

Bemerkungen hinsichtlich eines Widerspruchs

☐ Die zusätzlichen Gebühren wurden vom Anmelder unter Widerspruch gezahlt.

☐ Die Zahlung zusätzlicher Recherchengebühren erfolgte ohne Widerspruch.

WEITERE ANGABEN PCT/ISA/ 210

Fortsetzung von Feld I.2

Ansprüche Nr.: 3-7, 10-17

Die gesamte Anmeldung enthält nicht genügend Informationen, um folgende Schritte der beanspruchten Verfahren auf ihre technische Merkmale hin zu analysieren:

1. Die Antennengewichtsbestimmung, insbesondere die Bestimmung der Kovarianzmatrix, die Auswahl im Auswahlverfahren und die Bestimmung der Antennengewichte aus den ausgewählten Elementen
2. Das Beamforming-Verfahren im Block WH
3. Die Bestimmung des Beamformingsignals (BFS)
4. Die Transformation im Block T
5. Die Verwendung der korrigierten Impulsantwort zur Bestimmung des Entscheidungssignals

Daher erfüllt die Anmeldung nicht die Erfordernisse von Artikel 5 PCT, da die Erfindung nicht ausreichend deutlich und vollständig offenbart ist, so daß ein Fachmann sie ausführen kann.

Somit kann der Schutzumfang der Ansprüche 3-7 und 10-17 nicht klar bestimmt werden und aus diesem Grund ist eine vollständige Recherche zu den genannten Ansprüchen sinnvollerweise nicht möglich.

Die Gegenstände der eingangs genannten Ansprüche 3-7 und 10-17 wurden daher überhaupt nicht recherchiert (Artikel 17(2)(a)(ii) PCT).

Der Anmelder wird darauf hingewiesen, daß Patentansprüche, oder Teile von Patentansprüchen, auf Erfindungen, für die kein internationaler Recherchenbericht erstellt wurde, normalerweise nicht Gegenstand einer internationalen vorläufigen Prüfung sein können (Regel 66.1(e) PCT). In seiner Eigenschaft als mit der internationalen vorläufigen Prüfung beauftragte Behörde wird das EPA also in der Regel keine vorläufige Prüfung für Gegenstände durchführen, zu denen keine Recherche vorliegt. Dies gilt auch für den Fall, daß die Patentansprüche nach Erhalt des internationalen Recherchenberichtes geändert wurden (Art. 19 PCT), oder für den Fall, daß der Anmelder im Zuge des Verfahrens gemäß Kapitel II PCT neue Patentansprüche vorlegt.

INTERNATIONALER RECHERCHENBERICHT

Angaben zu Veröffentlichungen, die zur selben Patentfamilie gehören

Internationales Aktenzeichen
PCT/EP 03/01043

Im Recherchenbericht angeführtes Patentdokument		Datum der Veröffentlichung	Mitglied(er) der Patentfamilie			Datum der Veröffentlichung
US 6347234	B1	12-02-2002	US	6108565	A	22-08-2000
			US	6519478	B1	11-02-2003
			AU	9488598	A	05-04-1999
			BR	9812816	A	08-08-2000
			CA	2302547	A1	25-03-1999
			CN	1278971	T	03-01-2001
			EP	1062746	A2	27-12-2000
			NO	20001026	A	15-05-2000
			PL	339462	A1	18-12-2000
			WO	9914870	A2	25-03-1999

(12)特許協力条約に基づいて公開された国際出願

(19) 世界知的所有権機関
国際事務局

(43) 国際公開日
2004年11月4日 (04.11.2004)

PCT

(10) 国際公開番号
WO 2004/095730 A1

(51) 国際特許分類7: H04B 7/04, 7/06, H04J 11/00, 15/00

(21) 国際出願番号: PCT/JP2004/003614

(22) 国際出願日: 2004年3月18日 (18.03.2004)

(25) 国際出願の言語: 日本語

(26) 国際公開の言語: 日本語

(30) 優先権データ:
特願2003-116172 2003年4月21日 (21.04.2003) JP

(71) 出願人 (米国を除く全ての指定国について): 三菱電機株式会社 (MITSUBISHI DENKI KABUSHIKI KAISHA) [JP/JP]; 〒1008310 東京都千代田区丸の内二丁目2番3号 Tokyo (JP).

(72) 発明者; および
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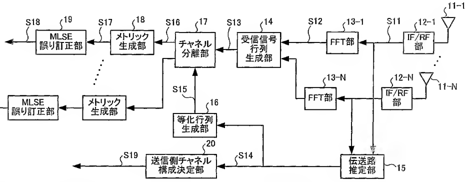
(74) 代理人: 酒井 宏明 (SAKAI, Hiroaki); 〒1000013 東京都千代田区霞が関三丁目2番6号 東京倶楽部ビルディング 酒井国際特許事務所 Tokyo (JP).

(81) 指定国 (表示のない限り、全ての種類の国内保護が可能): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU,

[続葉有]

(54) Title: RADIO COMMUNICATION APPARATUS, TRANSMITTER APPARATUS, RECEIVER APPARATUS AND RADIO COMMUNICATION SYSTEM

(54) 発明の名称: 無線通信装置、送信装置、受信装置および無線通信システム



19...MLSE ERROR CORRECTION PART
18...METRIC PRODUCING PART
17...CHANNEL SEPARATION PART
16...EQUALIZED MATRIX GENERATING PART
20...TRANSMITTING-SIDE CHANNEL STRUCTURE DECISION PART
14...RECEIVED SIGNAL MATRIX GENERATING PART
13-1...FFT PART
13-N...FFT PART
12-1...IF/RF PART
12-N...IF/RF PART
15...TRANSMISSION PATH ESTIMATION PART

(57) Abstract: For example, a channel division part (1) in the radio communication apparatus on a transmitting side divides, based on "channel structure information indicative of MIMO channel structure method" notified from the radio communication apparatus on a receiving side, a transmitted signal into a plurality of channels. An STC part (4) performs an STC (Space Time Coding) processing for each divided channel to realize transmission diversity, while a transmission path estimation part (15) in the radio communication apparatus on the receiving side estimates a transmission path between the transmitting and receiving sides. A transmitting-side channel structure decision part (20) decides, based on a result of that transmission path estimation, a physical structure of the radio communication apparatus on the transmitting side and a physical structure of the radio communication apparatus on the receiving side, the MIMO channel structure, and then notifies the radio communication apparatus on the transmitting side of a result of that decision, that is, the channel structure information.

(57) 要約: 本発明の無線通信装置では、たとえば、送信側の通信装置におけるチャネル分割部（１）が、受信側の通信装置から通知される「ＭＩＭＯチャネルの構成法を示すチャネル構成情報」に基づいて送信信号を複数のチャネルに分割し、ＳＴＣ（４）が、分割後のチャネル毎にＳＴＣ（Space Time Coding）処理による送信ダイバーシ

[続葉有]

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チを実現し、一方、受信側の通信装置における伝送路推定部（１５）が、送受信間の伝送路を推定し、送信側チャネル構成決定部（２０）が、前記伝送路推定結果、送信側の通信装置の物理的構成、および自装置の物理的構成に基づいて、ＭＩＭＯチャネルの構成を決定し、その決定結果であるチャネル構成情報を送信側の通信装置に通知する。

明 細 書

無線通信装置、送信装置、受信装置および無線通信システム

技術分野

本発明は、通信方式としてマルチキャリア変復調方式を採用する無線通信装置に関するものであり、特に、ＳＤＭ（Space Division Multiplexing）方式および送信ダイバーシチ技術を利用したシステムに適用可能な無線通信装置に関するものである。

背景技術

以下、従来の通信装置について説明する。広帯域信号を移動体環境において送受信する場合、周波数選択性フェージングの克服が必要となるが、この周波数選択性フェージングへの対応技術の一つとして、マルチキャリア、特に、ＯＦＤＭ（Orthogonal Frequency Division Multiplexing）が各種無線システムに採用されている。一方、更なる伝送容量の増大のために、複数アンテナを用いて２つ以上の信号を同時に伝送するＭＩＭＯ（Multiple Input Multiple Output）システムが注目を集めている。ＭＩＭＯシステムは、大きくＳＤＭによる方式と送信ダイバーシチによる方法に分けられ、後者に属する技術として、ＳＴＣ（Space Time Coding：時空符号化）と呼ばれる送信ダイバーシチ技術がある。

ここで、上記ＳＤＭ方式の一例（非特許文献１参照）を簡単に説明する。送信側の通信装置では、たとえば、同時送信する２チャネルのデータに対して個別に誤り訂正符号化を行い、その後、符号化後の各データに対して所定の変調処理を施し、それらの結果を対応するサブキャリアに配置する。そして、各サブキャリア上の信号は、ＩＦＦＴ（Inverse Fast Fourier Transform）処理によって個別に時間信号（ＯＦＤＭ信号）に変換され、さらに、ガードインターバルが付加され、高周波帯へアップコンバートされた後、対応する各送信アンテナより送信さ

れる。

また、受信側の通信装置では、まず、異なる受信アンテナで受信した高周波信号を個別にベースバンド信号に変換する。このとき、各ベースバンド信号は複数の信号（上記２チャネル）が混在する状態であるため、それらを分離する必要がある。つぎに、各ベースバンド信号は、ＦＦＴ（Fast Fourier Transform）処理によって周波数軸信号へ変換される。すなわち、ここでサブキャリア単位の信号（サブキャリア信号）となる。これらのサブキャリア信号は、複数チャネルの信号が多重されているため、重み付け制御（ウェイト制御）により各チャネルの受信信号として抽出される。非特許文献１においては、このウェイトの算出に、非所望チャネルを完全に抑圧するゼロフォーシング(Zero-Forcing)を用いている。チャネル単位に分離された受信信号は、それぞれ、復調処理でメトリック計算が実行され、誤り訂正処理が行われた後、最終的な各チャネルの受信信号として出力される。

このように、上記ＳＤＭ方式を採用する従来の通信装置では、複数チャネルを用いて異なる信号系列を同時送信することにより、単位時間当りの送信シンボル数を増加することができる。すなわち、伝送状態の良好な環境では高速な通信を実現できる。

一方、上記ＳＴＣ方式を採用する通信装置においては、一般的に、受信側によるチャネル分離に逆行列演算を必要としないので、少ない演算量で受信処理を実現できる、という特徴がある。また、受信側の装置構成を１本のアンテナで実現でき、さらに、低Ｓ／Ｎの環境下であっても優れた通信品質を確保できる、という特徴がある。なお、上記ＳＴＣ方式の理論的な信号処理については、下記非特許文献２，３に詳細に記述されている。

非特許文献１.

電子情報通信学会技術研究報告RCS2001-135「ＭＩＭＯチャネルにより１００Ｍｂｉｔ／ｓを実現する広帯域移動通信用ＳＤＭ－ＣＯＦＤＭ方式の提案」

非特許文献２.

S.M.Alamouti, "A Simple Transmit Diversity Technique for Wireless Communications",IEEE J. Se-lected Areas in Communications,val.16,pp.1451-1458,Oct.1998.

非特許文献３.

V.Tarokh, H.Jafarkhani, A.R.Calderbank,"Space-time Block Coding for Wireless Communications : Performance Results", IEEE Journal OnSelected Areas in Communications, Vol.17, pp.451-460,No.3, March 1999.

しかしながら、上記、ＳＤＭ方式を採用する従来の通信装置においては、チャネル分離に逆行列演算が必要となるので、演算量が増大する、という問題があった。また、たとえば、上記逆行列演算において逆行列が存在しない（または行列式が０に近い）場合は、Ｓ／Ｎ（Signal to Noise ratio）の急激な劣化が起きる、という問題があった。また、同時送信チャネル数以上の受信アンテナが必要となる、という問題もあった。

また、ＳＴＣ方式を採用する従来の通信装置においては、同一信号を複数回にわたって送信するため、送信シンボル数を増加させることが困難となる、という問題があった。

すなわち、ＳＴＣ方式を採用する通信装置とＳＤＭ方式を採用する通信装置は、上記のようにそれぞれ相反する特徴を有しているので、換言すれば、固有の問題点を抱えているので、最適なＭＩＭＯチャネルを構成するという点においてさらなる改善の余地がある。

本発明は、上記に鑑みてなされたものであって、それぞれの方式の特徴点を実現し、更なる高速化を実現することによって、最適なＭＩＭＯチャネルを構成可能な無線通信装置を提供することを目的とする。

発明の開示

本発明にかかる無線通信装置にあっては、複数の送信アンテナと、１つまたは

複数の受信アンテナを備え、１つまたは複数のキャリアを用いた通信を行う無線通信装置であって、受信側の通信装置から通知される「ＭＩＭＯ（Multiple Input Multiple Output）チャネルの構成法を示すチャネル構成情報」に基づいて送信信号を複数のチャネルに分割するチャネル分割手段と、さらに分割後のチャネル毎にＳＴＣ（Space Time Coding）処理による送信ダイバーシチを実現するＳＴＣ手段と、を含む送信処理部（後述する第２図の構成に相当）と、送受信間の伝送路を推定する伝送路推定手段と、前記伝送路推定結果、送信側の通信装置の物理的構成、および自装置の物理的構成に基づいて、ＭＩＭＯチャネルの構成を決定し、その決定結果であるチャネル構成情報を送信側の通信装置に通知するチャネル構成決定手段と、を含む受信処理部（後述する第３図の構成に相当）と、を備えることを特徴とする。

この発明によれば、送受信装置に備えられたアンテナ数，計算能力，伝送路状態など、種々のパラメータから最適なＭＩＭＯチャネルの構成（アンテナによるチャネル分割、ＳＴＣによるチャネル分割）を決定する。これにより、従来技術と比較して効率のよい通信を行うことができる。また、従来のＳＤＭ方式では逆行列が存在しない通信環境下であっても、ＳＴＣを適用することにより等化行列が生成できる可能性が高くなるため、ＳＤＭの特徴である高速な通信を維持しつつ、ＳＴＣの特徴である優れた通信品質を実現できる。

図面の簡単な説明

第１図は、本発明のシステムモデルを示す図であり、第２図は、本発明にかかる送信装置の実施の形態１の構成を示す図であり、第３図は、本発明にかかる受信装置の実施の形態１の構成を示す図であり、第４図は、本発明にかかる受信装置の実施の形態２の構成を示す図であり、第５図は、本発明にかかる送信装置の実施の形態３の構成を示す図である。

発明を実施するための最良の形態

以下に、本発明にかかる無線通信装置の実施の形態を図面に基づいて詳細に説明する。なお、この実施の形態によりこの発明が限定されるものではない。

実施の形態１.

まず、本発明にかかる無線通信装置において実行される処理を理論的に説明する。ここでは、サブキャリア数を１として説明する。

送信アンテナｉから受信アンテナｋへの伝送路ゲインをh_{ik}と表すと、たとえば、送信アンテナが２本の場合、ＳＤＭ方式は、下記（１）式で表すことができる。ただし、r_jは受信アンテナｊにおける受信信号を表し、x_jは送信アンテナｊ（チャネルｊと等価）における送信信号を表す。また、雑音は無視する。

$$\begin{bmatrix} r_1 \\ r_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{21} \\ h_{12} & h_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \quad \cdots (1)$$

一方、ＳＴＣ方式も、特定の信号配置マトリクスを用いた場合、（１）式と同様の記述が可能である。たとえば、送信アンテナ２、Ｒａｔｅ＝１のマトリクスを使用する場合、時刻ｎにおける受信信号をy_nとすれば、下記（２）式のように表すことができる。

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{21} \\ h_{21}^* & -h_{11}^* \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \quad \cdots (2)$$

ＳＤＭ方式との違いは受信アンテナが１本のため伝送路ゲインが２種の値しか現れない点である（ＳＴＣのブロック内では伝送路の変動はないものと仮定）。上記（１）式と（２）式からわかるようにＳＤＭとＳＴＣは全く同一の形で表現が可能である。

第１図は、ＳＤＭ方式とＳＴＣ方式を同時に使用する場合における、本実施の形態のシステムモデルを示す図である。ここでは、４つの送信アンテナ，２つの受信アンテナで２チャネルのＳＴＣ処理を想定する。また、送信アンテナＴｘ１，Ｔｘ２を一つのＳＤＭチャネル（従来のＳＤＭの場合の送信アンテナ１本に相当

：ＳＤＭｃｈ１と表記）と見なし、ＳＴＣ処理後の信号を送信する。また、送信アンテナＴｘ３，Ｔｘ４により構成されるＳＤＭｃｈ２ においても、ＳＴＣ処理後の信号を送信する。この場合は、送信信号s_1，s_2，s_3，s_4の４シンボルを２単位時間で送信することになる。

受信アンテナｎの時刻ｔにおける信号を$r_{n,t}$とすれば、受信信号は、上記（１）式と（２）式より、下記（３）式のようにＳＤＭおよびＳＴＣを完全に統合した形で記述することができる。

$$\begin{bmatrix} r_{1,1} \\ r_{1,2} \\ r_{2,1} \\ r_{2,2} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{21} & h_{31} & h_{41} \\ h_{21}^* & -h_{11}^* & h_{41}^* & -h_{31}^* \\ h_{12} & h_{22} & h_{32} & h_{42} \\ h_{22}^* & -h_{12}^* & h_{42}^* & -h_{32}^* \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ s_4 \end{bmatrix} \quad \cdots (3)$$

上記（３）式を一般化すると、下記（４）式のように表すことができる。

$$R = G \cdot S \quad \cdots (4)$$

そして、上記Ｇに逆行列が存在する場合、ＳＤＭとＳＴＣとを合わせた４チャネルの分離が可能となる。

ＳＴＣを表す信号配置マトリクスをＡ（ＳＤＭｃｈ１），Ｂ（ＳＤＭｃｈ２）とし、上記例による下記（５）式を適用した場合（Ａ，Ｂの添字は受信アンテナ番号）、行列Ｇは、下記（６）式となる。

$$A_1 = \begin{bmatrix} h_{11} & h_{21} \\ h_{21}^* & -h_{11}^* \end{bmatrix} \qquad B_1 = \begin{bmatrix} h_{31} & h_{41} \\ h_{41}^* & -h_{31}^* \end{bmatrix} \quad \cdots (5)$$

$$G = \begin{bmatrix} A_1 & B_1 \\ A_2 & B_2 \end{bmatrix} \quad \cdots (6)$$

行列Ｇが正則となるためには、Ｇの各行，列が平行とならなければよい。したがって、送受２アンテナの通常のＳＤＭ方式と比較した場合でも、逆行列が存在

する可能性は大きいので、ＭＩＭＯの適用領域を広げることができる。

つづいて、上記理論を実現する送信側の通信装置（以下、送信装置と呼ぶ）および受信側の通信装置（以下、受信装置と呼ぶ）の動作を、図面を用いて具体的に説明する。第２図は、本発明にかかる送信装置の実施の形態１の構成を示す図であり、第３図は、本発明にかかる受信装置の実施の形態１の構成を示す図である。

第２図に示す送信装置は、後述するチャネル構成制御情報Ｓ８に基づいて送信信号Ｓ１を複数チャネルに分割するチャネル分割部１と、分割後の各チャネルの送信信号Ｓ２に対して誤り訂正符号化処理を実行する畳み込み符号化部２と、符号化データＳ３に対して所定の変調処理を実行する変調部３と、変調信号Ｓ４に対して送信する時間およびアンテナを割り当てるＳＴＣ部４と、各アンテナに割り当てられたサブキャリア上の送信信号Ｓ５を時間軸上の信号（ベースバンド信号Ｓ６）に変換するＩＦＦＴ部５－１～５－Ｎ（Ｎは２以上の整数）と、ベースバンド信号Ｓ６を高周波帯へ変換するＩＦ／ＲＦ部６－１～６－Ｎと、送信アンテナ７－１～７－Ｎと、後述する受信装置側からフィードバックされてくるチャネル構成情報Ｓ７から上記チャネル構成制御情報Ｓ８を生成する送信チャネル構成制御部８と、を備える。なお、ここでは、説明の便宜上、特定のチャネルにおける動作を説明するが、他のチャネルについても同様に動作する。

また、第３図に示す受信装置は、受信アンテナ１１－１～１１－Ｎ（１つの場合も含む）と、高周波信号をベースバンド信号Ｓ１１に変換するＩＦ／ＲＦ部１２－１～１２－Ｎと、ベースバンド信号Ｓ１１を周波数軸上の信号（周波数信号Ｓ１２）に変換するＦＦＴ部１３－１～１３－Ｎと、チャネル構成情報（送受信アンテナ間でどのようにＳＤＭチャネル，ＳＴＣチャネルが構成されているかを示す情報）にしたがって受信信号行列Ｓ１３（（４）式のＲに相当）を生成する受信信号行列生成部１４と、受信信号（ベースバンド信号Ｓ１１）中の既知パターンを利用して伝送路推定を行う伝送路推定部１５と、伝送路情報Ｓ１４およびチャネル構成にしたがって等化行列Ｓ１５（（４）式のＧの逆行列に相当）を生

成する等化行列生成部１６と、受信信号行列Ｓ１３と等化行列Ｓ１５から各サブキャリア上の送信信号推定値Ｓ１６を算出するチャネル分離部１７と、送信信号推定値Ｓ１６に基づいて誤り訂正用のメトリック情報Ｓ１７を生成するメトリック生成部１８と、メトリック情報Ｓ１７に誤り訂正を適用して出力信号Ｓ１８を得るＭＬＳＥ（Maximum Likelihood Sequence Estimation）誤り訂正部１９と、伝送路情報Ｓ１４，受信アンテナの本数，自局の計算能力等から送信装置側のチャネル構成情報Ｓ１９を生成する送信側チャネル構成決定部２０と、を備える。なお、ここでは、説明の便宜上、特定のチャネルにおける動作を説明するが、他のチャネルについても同様に動作する。

ここで､上記送信装置および受信装置の動作を詳細に説明する｡送信装置では、ＭＩＭＯチャネルをどのように構成して送信すべきかを示すチャネル構成情報Ｓ７を受信装置側から受け取る。送信チャネル構成制御部８では、チャネル構成情報Ｓ７からチャネル構成制御情報Ｓ８を生成する。

チャネル分割部１では、チャネル構成制御情報Ｓ８の指示にしたがってユーザからの送信信号Ｓ１を複数のチャネルに分割する。たとえば、ＳＤＭによる２チャネルとＳＴＣによる２チャネルに分割する場合は、送信信号Ｓ１をＳＤＭ分の２チャネルに分割し、分割後の送信信号に対してさらにＳＴＣ処理を適用する。具体的には、畳み込み符号化部２がチャネル分割後の送信信号Ｓ２に対して誤り訂正畳み込み符号化処理を実行し、変調部３が符号化データＳ３を変調し、そして、ＳＴＣ部４が、変調信号Ｓ４に対して送信すべき時間および送信アンテナを割り当て各送信アンテナに分配する。

ＩＦＦＴ部５－１～５－Ｎでは、分配された送信信号Ｓ５をサブキャリア上に配置し、時間軸上の信号（ベースバンド信号Ｓ６）に変換する。そして、ＩＦ／ＲＦ部６－１～６－Ｎが、ベースバンド信号Ｓ６を高周波帯へアップコンバートして送信する。なお、実際には伝送路推定用の既知信号付加等の処理も行われるが、簡単のためその説明を省略する。なお、他のチャネルでも、上記と同様の手順で送信処理を行う。

また、受信装置では、アンテナ１１－１～１１－Ｎで高周波信号を受信後、ＩＦ／ＲＦ部１２－１～１２－Ｎがベースバンド信号Ｓ１１を生成する。伝送路推定部１５では、ベースバンド信号Ｓ１１中に含まれている既知パターンを用いて各送受信アンテナ間の伝送路推定を行う。そして、等化行列生成部１６が、チャネル分離のための等化行列G^{-1}（ＳＴＣの信号配置マトリクスから求まる信号配置マトリクス：チャネル毎の等化行列）を算出する。

一方、ＦＦＴ部１３－１～１３－Ｎでは、ベースバンド信号Ｓ１１中のユーザデータを周波数信号Ｓ１２に変換し、各サブキャリア上の信号として取り出す。受信信号行列生成部１４では、指定したＭＩＮＯチャネル構成に基づいて周波数信号Ｓ１２から受信信号行列Ｓ１３（（３）式のＲ）を生成する。そして、チャネル分離部１７では、受信信号行列Ｓ１３と等化行列Ｓ１５から送信信号推定値Ｓ１６を計算する。

メトリック生成部１８では、送信信号推定値Ｓ１６から誤り訂正用のメトリック情報Ｓ１７を算出する。そして、ＭＬＳＥ誤り訂正部１９が、誤り訂正処理を実行し、最終的な出力信号Ｓ１８を得る。

なお、本実施の形態では、受信装置側から送信装置側にＭＩＭＯチャネル構成を指定する必要がある。そこで、送信側チャネル構成決定部２０が、様々なパラメータを用いて、具体的にいうと、伝送路情報Ｓ１４（受信信号のＳ／Ｎ等），送受信装置のアンテナ本数，計算能力等を用いて、ＭＩＭＯチャネルの構成を決定する。そして、送信装置に対して上記決定結果であるチャネル構成情報Ｓ１９をチャネル構成情報Ｓ７としてフィードバックする。チャネル構成の決定法には様々なパターンが考えられる。たとえば、受信機の計算能力が極端に低い場合は、伝送路の状態が良いときであってもチャネル分離が容易なＳＴＣチャネルを優先して選択する。逆に、送受信機とも十分な数のアンテナおよび計算能力を有し、伝送路状態がＭＩＭＯに適する場合（アンテナ間の相関が小さい場合）には、同時送信チャネル数の多いＳＤＭ構成を選択する。

このように、本実施の形態においては、各装置に備えられたアンテナ数，計算

能力，伝送路状態など、種々のパラメータから最適なＭＩＭＯチャネルの構成（アンテナによるチャネル分割、ＳＴＣによるチャネル分割）を決定する。これにより、効率のよい通信を行うことができる。また、従来のＳＤＭ方式では逆行列が存在しない通信環境下であっても、ＳＴＣを適用することにより等化行列が生成できる可能性が高くなるため、ＳＤＭの特徴である高速な通信を維持しつつ、ＳＴＣの特徴である優れた通信品質を実現できる。

実施の形態２.

第４図は、本発明にかかる受信装置の実施の形態２の構成を示す図である。この受信装置は、伝送路のコヒーレント帯域幅を測定するコヒーレント帯域測定部２１ａと、コヒーレント帯域幅情報Ｓ２０および受信信号中の既知パターンを用いて伝送路推定を行う伝送路推定部１５ａと、を備える。なお、先に説明した実施の形態１と同様の構成については、同一の符号を付してその説明を省略する。ここでは、実施の形態１と異なる動作についてのみ説明する。

コヒーレント帯域測定部２１ａでは、ベースバンド信号Ｓ１１を定期的に観測し、現在の伝送路におけるコヒーレント帯域幅（伝送路がほぼ一定と見なせる周波数幅）を算出する。通常、この算出には既知信号が必要となるため、たとえば、パイロット信号部分が用いられる。コヒーレント帯域幅内はほぼ一定の伝送路と見なせることから、伝送路推定部１５ａでは、コヒーレント帯域幅情報Ｓ２０（瞬時の伝送路においてほぼ同一の伝送路利得を有する周波数帯域を表す情報。たとえば、１００ＭＨｚの信号帯域内において、１ＭＨｚ幅では伝送路の変動が無視できる場合に、コヒーレント帯域１ＭＨｚという情報となる。）で示された帯域幅内の１サブキャリアについて伝送路推定処理を行う。すなわち、コヒーレント帯域情報Ｓ２０により、信号帯域を同一の伝送路情報を持ついくつかのサブキャリアグループに分割する。そして、このグループ内において一度だけ伝送路推定処理および等化行列生成処理を行い、グループ内の全てのサブキャリアで同一の等化行列を使用する。

なお、上記伝送路推定部１５ａでは、上記に限らず、たとえば、サブキャリア

グループ内の複数サブキャリアについて伝送路推定を行い、その結果を平均化することとしてもよい。

このように、本実施の形態では、伝送路推定処理および等化行列生成処理をコヒーレント帯域内のサブキャリアグループ毎に一度だけ行うこととした。これにより、実施の形態１と同様の効果に加えて、さらに計算量を大幅に削減することが可能となり、装置構成の簡略化を実現できる。

実施の形態３.

第５図は、本発明にかかる送信装置の実施の形態３の構成を示す図である。この送信装置は、各送信チャネルのデータに送信アンテナ単位の複素乗算を行って送信方向を制御するビームフォーミング部９－１～９－Ｍ（２以上の整数）と、各送信アンテナに対応したビームフォーミング制御後の全送信信号を加算する加算部１０－１～１０－Ｎと、を備える。なお、先に説明した実施の形態１と同様の構成については、同一の符号を付してその説明を省略する。ここでは、実施の形態１と異なる動作についてのみ説明する。

実施の形態１では、ＳＴＣ処理後の送信信号Ｓ５が各送信アンテナから無指向で送信されていた。これに対して、本実施の形態では、送信信号Ｓ５に対して複数アンテナによるビームフォーミングを適用する。なお、本実施の形態では、ＳＴＣ処理後の送信チャネル数と送信アンテナ数が一致しなくてもよい。

具体的には、ビームフォーミング部９－１～９－Ｍが、各送信チャネルに対して独自の方向制御を行い、送信アンテナ単位に分配する。方向制御後の送信信号Ｓ９は、加算部１０－１～１０－Ｎにてアンテナ単位に加算され、ＩＦＦＴ部５－１～５－ＮにてＩＦＦＴ処理実行後、高周波帯にアップコンバートされて送信される。なお、図８では、説明の便宜上、一部のビームフォーミング部からの出力が加算されていないが、実際は全てのビームフォーミング部の出力が加算される。最適なビームフォーミングとは、「同時送信されるＳＤＭチャネルが互いに直交チャネルとなること」であることが、たとえば、電子情報通信学会技術研究報告RCS2002-53 「ＭＩＭＯチャネルにおける固有ビーム空間分割多重（E-SDM)

方式」に記載されている。ビームフォーミング部では、送受信機間に直交チャネルを形成するように各アンテナのウエイトを制御する。ウエイトの算出には伝送路の情報が必要であるが、この情報は受信機側からフィードバック回線により通知される。

このように、本実施の形態においては、ビームフォーミングにより送信電力を集中することとした。これにより、さらに、効率のよい通信が可能となる。また、送信チャネル数と送信アンテナ数が一致しなくてもよいことから、チャネル選択の自由度が大きくなるので、より良好な通信特性を確保することができる。

産業上の利用可能性

以上のように、本発明にかかる無線通信装置は、通信方式としてマルチキャリア変復調方式を採用する場合の技術として有用であり、特に、ＳＤＭ方式および送信ダイバーシチ技術を利用したシステムに適用可能な無線通信装置として適している。

請 求 の 範 囲

1．　複数の送信アンテナを備え、１つまたは複数のキャリアを用いた通信を行う送信側の無線通信装置において、

受信側の通信装置から通知される「ＭＩＭＯ（Multiple Input Multiple Output）チャネルの構成法を示すチャネル構成情報」に基づいて送信信号を複数のチャネルに分割するチャネル分割手段と、

さらに分割後のチャネル毎にＳＴＣ（Space Time Coding）処理による送信ダイバーシチを実現するＳＴＣ手段と、

を備えることを特徴とする無線通信装置。

2．　前記ＳＴＣ処理後の各送信チャネルに対して複素乗算による個別の方向制御を行い、各送信アンテナ単位に分配するビームフォーミング手段と、

前記各送信アンテナに対応した方向制御後の全送信信号を加算する加算手段と、

を備えることを特徴とする請求の範囲第１項に記載の無線通信装置。

3．　１つまたは複数の受信アンテナを備え、１つまたは複数のキャリアを用いた通信を行う受信側の無線通信装置において、

送受信間の伝送路を推定する伝送路推定手段と、

前記伝送路推定結果、送信側の通信装置の物理的構成、および自装置の物理的構成に基づいて、ＭＩＭＯ（Multiple Input Multiple Output）チャネルの構成を決定し、その決定結果であるチャネル構成情報を送信側の通信装置に通知するチャネル構成決定手段と、

を備えることを特徴とする無線通信装置。

4．　前記チャネル構成決定手段は、前記伝送路推定結果、送信側の通信装置および自装置のアンテナ本数、計算能力、の少なくともいずれか一つの情報に基づ

いてチャネル構成情報を生成することを特徴とする請求の範囲第３項に記載の無線通信装置。

５．　さらに、受信信号の観測により伝送路におけるコヒーレント帯域幅を測定するコヒーレント帯域測定手段、

を備え、

前記伝送路推定手段は、前記測定結果に基づいて、信号帯域を、同一の伝送路情報を持ついくつかのサブキャリアグループに分割し、当該サブキャリアグループを単位として伝送路推定を行うことを特徴とする請求の範囲第４項に記載の無線通信装置。

６．　前記サブキャリアグループ内の複数サブキャリアについて伝送路推定を行い、その結果を平均化することを特徴とする請求の範囲第５項に記載の無線通信装置。

７．　複数の送信アンテナと、１つまたは複数の受信アンテナを備え、１つまたは複数のキャリアを用いた通信を行う無線通信装置において、

受信側の通信装置から通知される「ＭＩＭＯ（Multiple Input Multiple Output）チャネルの構成法を示すチャネル構成情報」に基づいて送信信号を複数のチャネルに分割するチャネル分割手段と、

さらに分割後のチャネル毎にＳＴＣ（Space Time Coding）処理による送信ダイバーシチを実現するＳＴＣ手段と、

を含む送信処理部と、

送受信間の伝送路を推定する伝送路推定手段と、

前記伝送路推定結果、送信側の通信装置の物理的構成、および自装置の物理的構成に基づいて、ＭＩＭＯチャネルの構成を決定し、その決定結果であるチャネル構成情報を送信側の通信装置に通知するチャネル構成決定手段と、

を含む受信処理部と、

を備えることを特徴とする無線通信装置。

８．　前記チャネル構成決定手段は、前記伝送路推定結果、送信側の通信装置および自装置のアンテナ本数、計算能力、の少なくともいずれか一つの情報に基づいてチャネル構成情報を生成することを特徴とする請求の範囲第７項に記載の無線通信装置。

９．　さらに、受信信号の観測により伝送路におけるコヒーレント帯域幅を測定するコヒーレント帯域測定手段、

を備え、

前記伝送路推定手段は、前記測定結果に基づいて、信号帯域を、同一の伝送路情報を持ついくつかのサブキャリアグループに分割し、当該サブキャリアグループを単位として伝送路推定を行うことを特徴とする請求の範囲第８項に記載の無線通信装置。

１０．　前記サブキャリアグループ内の複数サブキャリアについて伝送路推定を行い、その結果を平均化することを特徴とする請求の範囲第９項に記載の無線通信装置。

１１．　複数の送信アンテナを備え、１つまたは複数のキャリアを用いて受信装置へ送信信号を送信する送信装置において、

前記受信装置から通知される「ＭＩＭＯ（Multiple Input Multiple Output）チャネルの構成法を示すチャネル構成情報」に基づいて、送信信号を複数の送信チャネルに分割するチャネル分割手段と、

前記分割後の各送信チャネルの送信信号に対する、ＳＴＣ（Space Time Coding）処理による送信ダイバーシチを実現するＳＴＣ手段と、

を備えることを特徴とする送信装置。

１２． 前記ＳＴＣ処理後の各送信チャネルの送信信号に対して複素乗算による個別の方向制御を行い、各送信アンテナ単位に分配するビームフォーミング手段と、

前記各送信アンテナに対応した方向制御後の全送信信号を加算する加算手段と、

をさらに備えることを特徴とする請求の範囲第１１項に記載の送信装置。

１３． １つまたは複数の受信アンテナを備え、１つまたは複数のキャリアを用いて送信装置から送信される信号を受信する受信装置おいて、

前記送信装置との間の伝送路を推定する伝送路推定手段と、

前記伝送路推定手段が推定した伝送路推定結果と、前記送信装置の物理的構成と、自装置の物理的構成と、に基づいて、ＭＩＭＯ（Multiple Input Multiple Output）チャネルの構成を決定し、その決定結果であるチャネル構成情報を前記送信装置に通知するチャネル構成決定手段と、

を備えることを特徴とする受信装置。

１４． さらに、前記送信装置からの受信信号の観測により伝送路におけるコヒーレント帯域幅を測定するコヒーレント帯域測定手段、

を備え、

前記伝送路推定手段は、前記コヒーレント帯域測定手段による測定結果に基づいて、信号帯域を、同一の伝送路情報を持つ複数のサブキャリアグループに分割し、該サブキャリアグループを単位として伝送路推定を行うことを特徴とする請求の範囲第１３項に記載の受信装置。

１５． 前記伝送路推定手段は、サブキャリアグループ内の複数サブキャリアについて伝送路推定を行い、その結果を平均化することを特徴とする請求の範囲第

１４項に記載の受信装置。

１６．　前記チャネル構成決定手段は、前記伝送路推定結果と、前記送信装置のアンテナ数と、自装置のアンテナ数と、前記送信装置の計算能力と、自装置の計算能力と、の少なくともいずれか一つの情報に基づいてチャネル構成情報を生成することを特徴とする請求の範囲第１３項に記載の受信装置。

１７．　複数の送信アンテナを備え、１つまたは複数のキャリアを用いて受信装置へ送信信号を送信する送信装置と、１つまたは複数の受信アンテナを備え、前記送信装置から送信される信号を受信する受信装置と、を含む無線通信システムにおいて、

前記送信装置は、

前記受信装置から通知される「ＭＩＭＯ（Multiple Input Multiple Output）チャネルの構成法を示すチャネル構成情報」に基づいて、送信信号を複数の送信チャネルに分割するチャネル分割手段と、

前記分割後の各送信チャネルの送信信号に対する、ＳＴＣ（Space Time Coding）処理による送信ダイバーシチを実現するＳＴＣ手段と、

を備え、

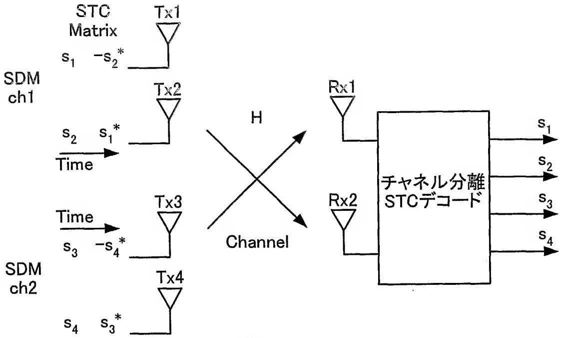
前記受信装置は、

前記送信装置との間の伝送路を推定する伝送路推定手段と

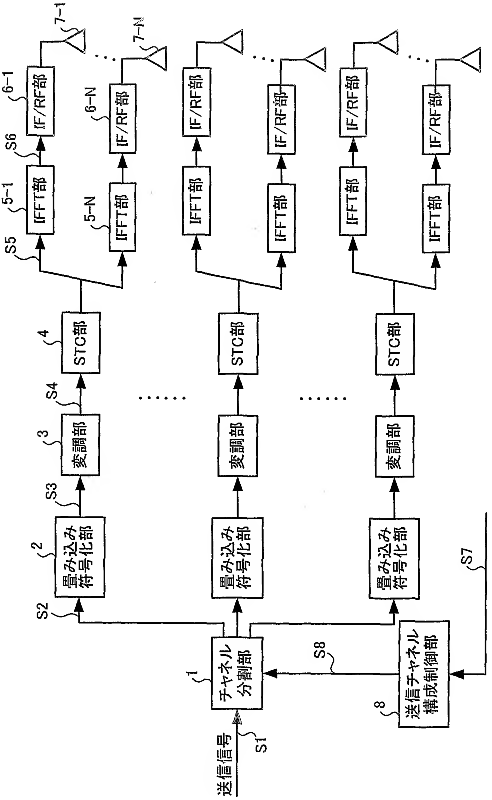
前記伝送路推定手段が推定した伝送路推定結果と、前記送信装置の物理的構成と、自装置の物理的構成と、に基づいて、ＭＩＭＯ（Multiple Input Multiple Output）チャネルの構成を決定し、その決定結果であるチャネル構成情報を前記送信装置に通知するチャネル構成決定手段と、

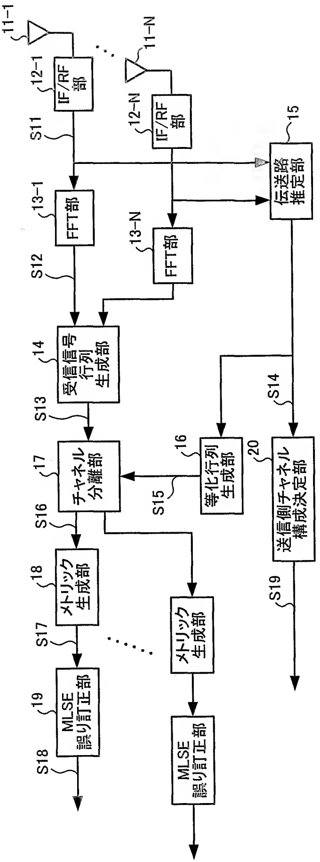
を備えることを特徴とする無線通信システム。

第１図


STC
Matrix
Tx1
s1 −s2*
SDM
ch1
Tx2
s2 s1*
Time
Time
Tx3
s3 −s4*
SDM
ch2
Tx4
s4 s3*
H
Channel
Rx1
Rx2
チャネル分離
STCデコード
s1
s2
s3
s4

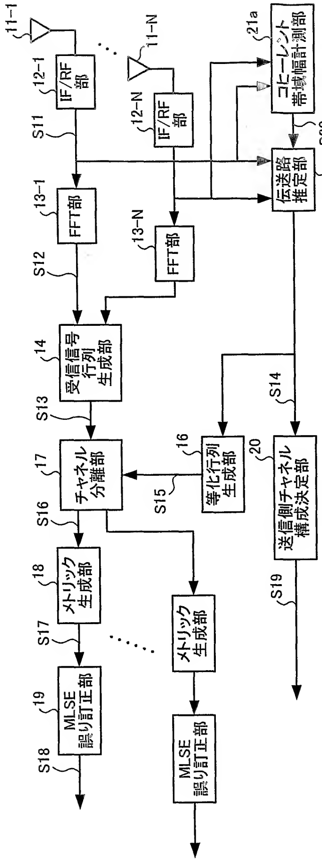
第2図


送信信号
S1
1
チャネル分割部
S8
8
送信チャネル構成制御部
S7
S2
2
畳み込み符号化部
S3
3
変調部
S4
4
STC部
S5
5-1
IFFT部
5-N
S6
6-1
IF/RF部
6-N
7-1
7-N

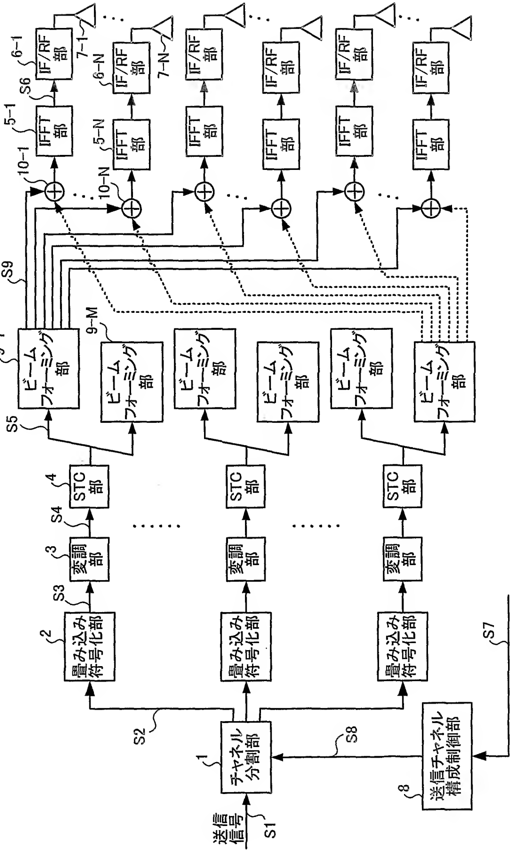

11-1
11-N
12-1
IF/RF部
12-N
IF/RF部
15
伝送路推定部
S11
13-1
FFT部
13-N
FFT部
S12
14
受信信号行列生成部
S13
S14
16
等化行列生成部
20
送信側チャネル構成決定部
17
チャネル分離部
S15
S16
18
メトリック生成部
メトリック生成部
S17
S19
19
MLSE誤り訂正部
MLSE誤り訂正部
S18

第3図

第４図


11-1
11-N
12-1
IF/RF部
12-N
IF/RF部
S11
13-1
FFT部
13-N
FFT部
S12
14
受信信号行列生成部
S13
21a
コヒーレント帯域幅計測部
S20
伝送路推定部
15a
S14
16
等化行列生成部
S15
17
チャネル分離部
20
送信側チャネル構成決定部
S16
18
メトリック生成部
メトリック生成部
S17
19
MLSE誤り訂正部
MLSE誤り訂正部
S18
S19

第５図


送信信号
S1
チャネル分割部
1
S2
S8
送信チャネル構成制御部
8
S7
畳み込み符号化部
2
S3
変調部
3
S4
STC部
4
S5
ビームフォーミング部
9-1
9-M
S9
10-1
10-N
IFFT部
5-1
5-N
IF/RF部
6-1
6-N
S6
7-1
7-N

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2004/003614

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl^7 H04B7/04, 7/06, H04J11/00, 15/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl^7 H04B7/02-7/12, H04J11/00, 15/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Toroku Jitsuyo Shinan Koho	1994-2004
Kokai Jitsuyo Shinan Koho	1971-2004	Jitsuyo Shinan Toroku Koho	1996-2004

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	Toru ARAIDA et al., "Jikukan Block Fugo Gyoretsu o Mochiita Tekio Hencho", The Institute of Electronics, Information and Communication Engineers, Gijutsu Kenkyu Hokoku, 27 February, 2002 (27.02.02), Vol.101, No.682, pages 31 to 36, SST2001-66	1,3,4,11,13,16 2,5-10,12,14,15,17
X A	Satoshi TOKI et al., "Saiteki Denryoku Haibun o Okonau Soshin Antenna Sentakugata MIMO Channel Denso Hoshiki", 2003 Nen The Institute of Electronics, Information and Communication Engineers, Sogo Taikai Koen Ronbunshu, 03 March, 2003 (03.03.03), page 622, B-5-163	3,4,13,16 1,2,5-12,14,15,17

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 June, 2004 (15.06.04)	29 June, 2004 (29.06.04)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	Yoshitaka HARA et al., "Sojushin Beam Keisei o Mochiiru MIMO System no Wait Seigyoho", The Institute of Electronics, Information and Communication Engineers, Gijutsu Kenkyu Hokoku, 23 August, 2002 (23.08.02), Vol.102, No.282, pages 33 to 40, RCS2002-152	3,4,13,16 1,2,5-12, 14,15,17
Y	Kazuya MIYASHITA et al., "MIMO Channel ni okeru Koyu Beam Kukan Bunkatsu Taju (E-SDM) Hoshiki", The Institute of Electronics, Information and Communication Engineers, Gijutsu Kenkyu Hokoku, 17 May, 2002 (17.05.02), Vol.102, No.86, pages 13 to 18, RCS2002-53	2,7,8,12, 17
Y	JP 2000-188585 A (Matsushita Electric Industrial Co., Ltd.), 04 July, 2000 (04.07.00), Par. Nos. [0096] to [0113]; Fig. 6 (Family: none)	5,6,9,10, 14,15
Y	JP 2002-198878 A (Toshiba Corp.), 12 July, 2002 (12.07.02), Par. No. [0027]; Fig. 1 (Family: none)	5,9,14

Ａ．　発明の属する分野の分類（国際特許分類（ＩＰＣ））
Ｉｎｔ．Ｃｌ⁷　Ｈ０４Ｂ７／０４，７／０６
Ｈ０４Ｊ１１／００，１５／００

Ｂ．　調査を行った分野
調査を行った最小限資料（国際特許分類（ＩＰＣ））
Ｉｎｔ．Ｃｌ⁷　Ｈ０４Ｂ７／０２－７／１２
Ｈ０４Ｊ１１／００，１５／００

最小限資料以外の資料で調査を行った分野に含まれるもの
日本国実用新案公報　　　　１９２２－１９９６年
日本国公開実用新案公報　　１９７１－２００４年
日本国登録実用新案公報　　１９９４－２００４年
日本国実用新案登録公報　　１９９６－２００４年

国際調査で使用した電子データベース（データベースの名称、調査に使用した用語）

Ｃ．　関連すると認められる文献

引用文献のカテゴリー＊	引用文献名　及び一部の箇所が関連するときは、その関連する箇所の表示	関連する請求の範囲の番号
Ｘ Ｙ	新井田統　他，時空間ブロック符号行列を用いた適応変調，電子情報通信学会技術研究報告，２７．０２．２００２，Ｖｏｌ．１０１，Ｎｏ．６８２，ｐ．３１－３６，ＳＳＴ２００１－６６	１，３，４，１１，１３，１６ ２，５－１０，１２，１４，１５，１７

☒ Ｃ欄の続きにも文献が列挙されている。　　☐ パテントファミリーに関する別紙を参照。

＊　引用文献のカテゴリー
「Ａ」特に関連のある文献ではなく、一般的技術水準を示すもの
「Ｅ」国際出願日前の出願または特許であるが、国際出願日以後に公表されたもの
「Ｌ」優先権主張に疑義を提起する文献又は他の文献の発行日若しくは他の特別な理由を確立するために引用する文献（理由を付す）
「Ｏ」口頭による開示、使用、展示等に言及する文献
「Ｐ」国際出願日前で、かつ優先権の主張の基礎となる出願の日の後に公表された文献
「Ｔ」国際出願日又は優先日後に公表された文献であって出願と矛盾するものではなく、発明の原理又は理論の理解のために引用するもの
「Ｘ」特に関連のある文献であって、当該文献のみで発明の新規性又は進歩性がないと考えられるもの
「Ｙ」特に関連のある文献であって、当該文献と他の１以上の文献との、当業者にとって自明である組合せによって進歩性がないと考えられるもの
「＆」同一パテントファミリー文献

国際調査を完了した日　１５．０６．２００４	国際調査報告の発送日　29.6.2004
国際調査機関の名称及びあて先 日本国特許庁（ＩＳＡ／ＪＰ） 郵便番号１００－８９１５ 東京都千代田区霞が関三丁目４番３号	特許庁審査官（権限のある職員）　５Ｊ　３３６０ 畑中　博幸 電話番号　０３－３５８１－１１０１　内線　３５３４

Ｃ（続き）．　関連すると認められる文献

引用文献のカテゴリー＊	引用文献名　及び一部の箇所が関連するときは、その関連する箇所の表示	関連する請求の範囲の番号
Ｘ Ａ	時慧　他，最適電力配分を行う送信アンテナ選択型ＭＩＭＯチャネル伝送方式，２００３年電子情報通信学会総合大会講演論文集，０３．０３．２００３，ｐ．６２２，Ｂ－５－１６３	３，４， １３，１６ １，２，５－ １２，１４， １５，１７
Ｘ Ａ	原嘉孝　他，送受信ビーム形成を用いるＭＩＭＯシステムのウエイト制御法，電子情報通信学会技術研究報告， ２３．０８．２００２，Ｖｏｌ．１０２，Ｎｏ．２８２， ｐ．３３－４０，ＲＣＳ２００２－１５２	３，４， １３，１６ １，２，５－ １２，１４， １５，１７
Ｙ	宮下和巳　他，ＭＩＭＯチャネルにおける固有ビーム空間分割多重（Ｅ－ＳＤＭ）方式，電子情報通信学会技術研究報告， １７．０５．２００２，，Ｖｏｌ．１０２，Ｎｏ．８６， ｐ．１３－１８，ＲＣＳ２００２－５３	２，７，８， １２，１７
Ｙ	ＪＰ　２０００－１８８５８５　Ａ（松下電器産業株式会社） ０４．０７．２０００， 段落【００９６】－【０１１３】，第６図，（ファミリーなし）	５，６，９， １０，１４， １５
Ｙ	ＪＰ　２００２－１９８８７８　Ａ（株式会社東芝） １２．０７．２００２， 段落【００２７】，第１図，（ファミリーなし）	５，９，１４

RADIO COMMUNICATION SYSTEM AND TRANSMISSION MODE SELECTING METHOD

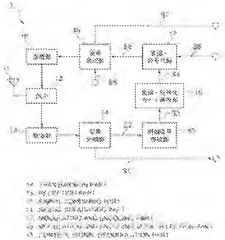
Publication number: WO2005002253 (A1)
Publication date: 2005-01-06
Inventor(s): KIKUCHI SHINGO [JP]; YOSHIDA SHOUSEI [JP]; KAKURA YOSHIKAZU [JP]; USHIROKAWA AKIHISA [JP]; KIMATA MASAYUKI [JP] +
Applicant(s): NEC CORP [JP]; KIKUCHI SHINGO [JP]; YOSHIDA SHOUSEI [JP]; KAKURA YOSHIKAZU [JP]; USHIROKAWA AKIHISA [JP]; KIMATA MASAYUKI [JP] +
Classification:
- international: *H04L12/56; H04W72/08;* **H04L12/56; H04W72/00;** (IPC1-7): H04Q7/22
- European: H04L1/00A8L; H04L12/56B; H04W88/06
Application number: WO2004JP09463 20040628
Priority number(s): JP20030187156 20030630

Also published as:
EP1641291 (A1)
US2006234643 (A1)
US7257408 (B2)
KR20060025197 (A)
CN1810051 (A)
more >>

Cited documents:
JP2002044168 (A)
JP2002271294 (A)
JP2003037554 (A)
JP2002101043 (A)
JP8181653 (A)

Abstract of **WO 2005002253 (A1)**

A radio communication system for quickly selecting an optimum transmission mode in accordance with the quality and condition of a propagation path. The radio communication system has first and second radio apparatuses capable of radio-communicating with each other. The first radio apparatus (2) comprises a propagation path environment estimation part (208) for estimating, from a signal outputted from the second radio apparatus (1), the propagation path environment between the first and second radio apparatuses and then outputting the estimation result as propagation path environment information, a propagation path quality estimation part (209) for estimating, from the signal outputted from the second radio apparatus (1), a propagation path quality between the first and second radio apparatuses and then outputting the estimation result as propagation path quality information; and a transmission part (211) for transmitting the propagation path environment information and propagation path quality information as well as data signals to the second radio apparatus (1). The second radio apparatus (1) comprises a transmission mode selecting part (16) for selecting, in accordance with the propagation path environment information, one of a plurality of tables in which a plurality of transmission modes having thresholds associated with the values of the propagation path environment information have been registered, and then selecting, in accordance with the propagation path quality information, one of the transmission modes registered in the selected table as the transmission mode used for the first radio apparatus (2).



(12)特許協力条約に基づいて公開された国際出願

(19) 世界知的所有権機関
国際事務局

(43) 国際公開日
2005 年1 月6 日 (06.01.2005)

PCT

(10) 国際公開番号
WO 2005/002253 A1

(51) 国際特許分類7: H04Q 7/22

(21) 国際出願番号: PCT/JP2004/009463

(22) 国際出願日: 2004 年6 月28 日 (28.06.2004)

(25) 国際出願の言語: 日本語

(26) 国際公開の言語: 日本語

(30) 優先権データ:
特願2003-187156 2003 年6 月30 日 (30.06.2003) JP

(71) 出願人 (米国を除く全ての指定国について): 日本電気株式会社 (NEC CORPORATION) [JP/JP]; 〒1088001 東京都港区芝五丁目７番１号 Tokyo (JP).

(72) 発明者; および

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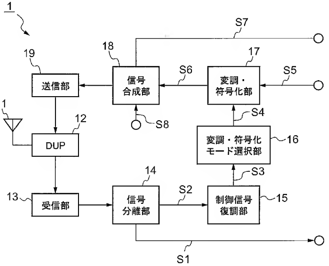
[続葉有]

(54) Title: RADIO COMMUNICATION SYSTEM AND TRANSMISSION MODE SELECTING METHOD

(54) 発明の名称: 無線通信システムおよび送信モード選択方法



19...TRANSMISSION PART
13...RECEPTION PART
18...SIGNAL COMBINING PART
14...SIGNAL SEPARATING PART
17...MODULATING AND ENCODING PART
16...MODULATION AND ENCODING MODE SELECTION PART
15...CONTROL SIGNAL DEMODULATION PART

(57) Abstract: A radio communication system for quickly selecting an optimum transmission mode in accordance with the quality and condition of a propagation path. The radio communication system has first and second radio apparatuses capable of radio-communicating with each other. The first radio apparatus (2) comprises a propagation path environment estimation part (208) for estimating, from a signal outputted from the second radio apparatus (1), the propagation path environment between the first and second radio apparatuses and then outputting the estimation result as propagation path environment information; a propagation path quality estimation part (209) for estimating, from the signal outputted from the second radio apparatus (1), a propagation path quality between the first and second radio apparatuses and then outputting the estimation result as propagation path quality information; and a transmission part (211) for transmitting the propagation path environment information and propagation path quality information as well as data signals to the second radio apparatus (1). The second radio apparatus (1) comprises a transmission mode selecting part (16) for selecting, in accordance with the propagation path environment information, one of a plurality of tables in which a plurality of transmission modes having thresholds associated with the values of the propagation path environment information have been registered, and then selecting, in accordance with the propagation path quality information, one of the transmission modes registered in the selected table as the transmission mode used for the first radio apparatus (2).

(57) 要約: 伝搬路品質および伝搬路状況に応じて最適な送信モードを迅速に選択するための無線通信システムである。本発明の無線通信システムは、互いに無線通信を行なう第一および第二無線装置を有し、第一無線装置（２）は、第二無線装置（１）から出力される信号から第二無線装置との伝搬路環境を推定した結果を伝搬路環境情報として、および第二無線装置との伝搬路品質を推定した結果を伝搬路品質情報としてそれぞれ

[続葉有]

WO 2005/002253 A1

(74) 代理人: 鈴木 弘男 (SUZUKI, Hiroh); 〒1030023 東京都中央区日本橋本町２丁目３番１号 茶の木屋ビル 鈴木国際特許事務所 Tokyo (JP).

(81) 指定国 (表示のない限り、全ての種類の国内保護が可能): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) 指定国 (表示のない限り、全ての種類の広域保護が可能): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), ユーラシア (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), ヨーロッパ (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

添付公開書類:
— 国際調査報告書

２文字コード及び他の略語については、 定期発行される各*PCT*ガゼットの巻頭に掲載されている「コードと略語のガイダンスノート」を参照。

出力する伝搬路環境推定部（２０８）および伝搬路品質推定部（２０９）と、伝搬路環境情報および伝搬路品質情報をデータ信号とともに第二無線装置（１）に送信する送信部（２１１）とを具備し、第二無線装置（１）は、伝搬路品質情報の値が対応する閾値とされる複数の送信モードが登録されている複数のテーブルのうちから、いずれかを伝搬路環境情報に応じて選択し、該選択したテーブルに登録されている送信モードのいずれかを伝搬路品質情報に応じて選択し、これを第一無線装置（２）への送信モードとする送信モード選択部（１６）を具備する。

明　細　書

無線通信システムおよび送信モード選択方法

技術分野

本発明は無線通信システムに関し、特に、伝搬路品質に応じて送信モードを切り換える無線通信システムに関する。

背景技術

無線通信システムにおいて、高速かつ高品質なデータ伝送を実現する方法として、伝搬路品質に応じて送信モードを切り換える方法がある。切り換えられる送信モードは伝搬路品質に応じて異なるものであるが、その内容を異ならせるパラメータとしては変調方式および符号化率が挙げられる。

送信側でｋビットの情報ビットに（ｎ－ｋ）ビットの冗長ビットを付加した誤り訂正符号の符号化率ｋ／ｎ、および、１回の変調でそれぞれ２ビット、４ビット、６ビットを伝送可能なＱＰＳＫ、１６ＱＡM、６４ＱＡM等の変調モードを伝搬路品質に応じて選択する。

符号化率および変調ビット数が大きいほど最大データ伝送速度も大きくなるが、目標とする通信品質（ブロック誤り率、ビット誤り率、スループット量などで示される）を満足させる伝搬路品質（信号対雑音比Ｓ／Ｎや信号電力対干渉比ＳＩＲで示される）も高くなる。

無線通信システムでは、伝搬路品質が無線装置間の見通しの有無、他の無線装置からの干渉等で変動する。このため、伝搬路品質に応じて、目標とする通信品質を満足させることができる変調方式・符号化率による送信モード（以下、変調・符号化モードと略称する）の中でデータ伝送速度が最大となる最適なモードで伝

送すれば、システムのスループットを最大化することができる。

上記の変調・符号化モード切換えの実現方法として、第７図に示されるように、伝搬路品質（ｄＢ）の範囲をあらかじめ固定した閾値として決定しておき、送受間で既知であるパイロット信号から求めた伝搬路品質に応じて変調・符号化モードを決定する方法がある。第７図に示される例では、伝搬路品質が１２ｄＢ以上では６４ＱＡＭの変調方式および符号化率Ｒ＝３／４による送信が行なわれ、伝搬路品質が５ｄＢ以上１２ｄＢ未満では１６ＱＡＭの変調方式および符号化率Ｒ＝１／２による送信が行なわれ、伝搬路品質が５ｄＢ未満ではＱＰＳＫの変調方式および符号化率Ｒ＝１／３による送信が行なわれる。

伝搬路品質は受信側で推定されて送信側に通知され、送信側は受信側から通知される伝搬路品質を上記の閾値と比較して伝搬路品質に応じた変調・符号化モードが選択される。しかしながら、たとえ伝搬路品質が同じでも伝搬路環境が異なれば最適な変調・符号化モードは異なる。上記伝搬路環境の決定要因にはマルチパス環境（パス数および遅延分散）、最大ドップラ周波数（移動速度）等がある。

上述したように、伝搬路品質が同じでも伝搬路環境が異なれば最適となる変調・符号化モードは異なり、逆に言うと伝搬路環境が変化した場合には最適な変調・符号化モードを選択する伝搬路品質の閾値は変化することとなる。伝搬路環境の変化が大きいほど最適な変調・符号化モードを選択する伝搬路品質の閾値の変化も大きい。このため伝搬路品質を固定の閾値と比較して変調・符号化モードを選択する方法の場合、閾値を最適な値とすることが難しい。

上記問題を解決する方法として、特許文献１（特開２００３－３７５５４号公報）に開示される、情報ブロック単位の受信誤りの有無に基づいて閾値を可変制御する方法がある。この方法ではパイロット信号の受信品質を閾値テーブルに保存された複数の閾値と比較し、どの変調・符号化モードを選択するかを決定し、決定内容を切替え指示として出力する。複数の閾値は、第８図に示されるように、

受信側からの受信誤り通知の有無に基づいて可変制御される。情報ブロックの受信が成功したときには現在用いている変調・符号化モードに対する伝搬路品質の閾値範囲の上限を所定の値Ｐdown ｄＢだけ下げ、情報ブロックの受信が所定回数だけ失敗したときには上記閾値の範囲の下限値を所定の値Ｐup ｄＢだけ上げる。これにより、変調・符号化モード選択に用いる最適な閾値が伝搬路品質に応じて設定される無線通信システムが提供される。

上述した従来技術のうち、伝搬路品質を固定の閾値と比較して変調・符号化モードを決定する場合には閾値を最適な値とすることが難しいという問題点がある。

特許文献１に開示される方法では、伝搬路環境の変化に応じて最適な閾値を設定することが可能であるが、伝搬路品質の閾値を最適値に移行させるのに多くの時間が必要となり、最適な閾値までの変動幅が大きいほど最適な閾値まで収束するのに必要な時間が大きくなる。

本発明は上述したような従来技術における事情に鑑みてなされたものであって、その目的とするところは、伝搬路品質および伝搬路状況に応じて最適な送信モードを迅速に選択することのできる無線通信システムおよび送信モード選択方法を提供することにある。

発明の開示

上記目的を達成するために、本発明の第１の主なる態様によれば、互いに無線通信を行なう第一無線装置と第二無線装置とを有する無線通信システムであって、第一無線装置は、第二無線装置からの信号から第二無線装置との伝搬路の環境を推定した結果を伝搬路環境情報として出力する伝搬路環境推定部と、第二無線装置からの信号から第二無線装置との伝搬路の品質を推定した結果を伝搬路品質情報として出力する伝搬路品質推定部と、伝搬路環境情報および伝搬路品質情報をデータ信号とともに第二無線装置に送信する送信手段とを具備し、第二無線装置

は、伝搬路品質情報の値が対応する閾値とされる複数の送信モードが登録されている複数のテーブルを備え、複数のテーブルのいずれかを伝搬路環境情報に応じて選択し、該選択したテーブルに登録されている送信モードのいずれかを伝搬路品質情報に応じて選択して第一無線装置への送信モードとする送信モード選択部を具備することを特徴とする無線通信システムが提供される。

上記第１の主なる態様に記載の無線通信システムは、下記のとおり、様々な副次的態様を採ることができる。

まず、第一無線装置は、第二無線装置からの信号における誤りを検出して誤り検出結果として出力する誤り検出部を備え、送信手段は伝搬路環境情報、伝搬路品質情報、そして誤り検出結果をデータ信号とともに第二無線装置に送信し、第二無線装置の送信モード選択部は、誤り検出結果に応じて選択した送信モードに対応してテーブルに登録されている閾値を書き換えることにしてもよい。

また、伝搬環境情報としてパス数を用いることにしてもよい。この場合、複数のテーブルがパス数$P1, P2, \cdots, PR$（$P1, P2, \cdots, PR$は自然数で、$P1<P2<\cdots<PR$を満たす）に対応するようにしてもよい。

また、伝搬路環境情報として最大ドップラ周波数を用いることにしてもよい。この場合、複数のテーブルが最大ドップラ周波数$f0, f1, \cdots, fR\text{-}1$（$f0<f1<\cdots<fR\text{-}1$）に対応し、閾値$xi$（$xi$は$fi<xi<fi+1$を満たす任意の数、$i$は０以上Ｒ－２以下の整数）に対し、最大ドップラ周波数fdが$xj\text{-}1<fd\leqq xj$（jは１以上、Ｒ－２以下の整数）のとき最大ドップラ周波数としてfj、$fd\leqq x0$のとき最大ドップラ周波数として$f0$、$fd>xR\text{-}2$のとき最大ドップラ周波数として$fR\text{-}1$を選択するようにしてもよい。

また、伝搬路環境情報として遅延分散を用いることにしてもよい。この場合、複数のテーブルが遅延分散$\sigma 0, \sigma P, \cdots, \sigma q\text{-}1$（$\sigma 0<\sigma 1<\cdots<\sigma R\text{-}1$）に対応し、閾値$xi$（$xi$は$\sigma i<xi<\sigma i+1$を満たす任意の数、$i$は０以上Ｒ－２以下

の整数）に対し、遅延分散σがx j-1＜σ≦x j（jは1以上R－2以下の整数）のとき遅延分散としてσj，σ≦x0のとき遅延分散としてσ0、σ＞xR-2のとき遅延分散としてσR-1を選択するようにしてもよい。

また、複数の選択テーブルがパス数P1，P2，…，PJ（P1，P2，…，PJはR以下の自然数でP1＜P2＜…＜PJを満たす）、最大ドップラ周波数f0，f1，…fK-1（KはR以下の自然数でJ×K＝Rを満たす）の組み合わせに対応するようにしてもよい。

また、複数のテーブルがパス数P1，P2，…，PJ（P1，P2，…，PJは自然数でP1＜P2＜…＜PJ を満たす）、遅延分散σ0，σP，…，σk-1（LはR以下の自然数でJ×L＝R）の組み合わせ（ただしパス数が1のとき、遅延分散を伝搬路環境情報として使用しない）に対応するようにしてもよい。

また、複数のテーブルが最大ドップラ周波数f0～fK-1、遅延分散σ0～σL-1（LはR以下の自然数でK×L＝R）の組み合わせに対応するようにしてもよい。

また、複数のテーブルがパス数P1，P2，…，PJ、最大ドップラ周波数f0～fK-1、及び遅延分散σ0～σL-1（J，K，L，RはJ×K×L＝Rを満たす自然数）の組み合わせ（ただしパス数が1のとき、遅延分散を伝搬路環境情報として使用しない）に対応するようにしてもよい。

また、伝搬路品質情報として信号対干渉比を用いることにしてもよい。

また、伝搬路品質情報として信号対雑音比を用いることにしてもよい。

また、送信モードのパラメータとして変調方式を用いることにしてもよい。

また、送信モードのパラメータとして符号化率を用いることにしてもよい。

また、送信モードのパラメータとして送信電力を用いることにしてもよい。

本発明の第2の主なる態様によれば、互いに無線通信を行なう第一無線装置と第二無線装置とを有する無線通信システムで行なわれる送信モード選択方法であって、第二無線装置からの信号から第二無線装置との伝搬路の環境を示す伝搬路

環境情報を推定する、第一無線装置が行なう、第１のステップと、第二無線装置からの信号から第二無線装置との伝搬路の品質を示す伝搬路品質情報を推定する、第一無線装置が行なう、第２のステップと、伝搬路環境情報および伝搬路品質情報をデータ信号とともに第二無線装置に送信する、第一無線装置が行なう、第３のステップと、記伝搬路品質情報の値が対応する閾値とされる複数の送信モードが登録されている複数のテーブルのいずれかを伝搬路環境情報に応じて選択し、該選択したテーブルに登録されている送信モードのいずれかを伝搬路品質情報に応じて選択して第一無線装置への送信モードとする、第二無線装置が行なう、第４のステップとを含むことを特徴とする送信モード選択方法が提供される。

本発明の第３の主なる態様によれば、互いに無線通信を行なう第一無線装置と第二無線装置とを有する無線通信システムで行なわれる送信モード選択方法であって、第二無線装置からの信号から第二無線装置との伝搬路の環境を示す伝搬路環境情報を推定する、第一無線装置が行なう、第１のステップと、第二無線装置からの信号から第二無線装置との伝搬路の品質を示す伝搬路品質情報を推定する、第一無線装置が行なう、第２のステップと、記第二無線装置からの信号における誤りを示す誤り検出結果を求める、第一無線装置が行なう、第３のステップと、伝搬路環境情報、伝搬路品質情報および誤り検出結果をデータ信号とともに第二無線装置に送信する、第一無線装置が行なう、第４のステップと、伝搬路品質情報の値が対応する閾値とされる複数の送信モードが登録されている複数のテーブルのいずれかを伝搬路環境情報に応じて選択し、該選択したテーブルに登録されている前記送信モードのいずれかを前記伝搬路品質情報に応じて選択して前記第一無線装置への送信モードとし、誤り検出結果に応じて選択した送信モードに対応してテーブルに登録されている閾値を書き換える、第二無線装置が行なう、第５のステップとを含むことを特徴とする送信モード選択方法が提供される。

上記各態様を有する本発明は、伝搬路環境情報に応じて選択される複数のテー

ブルを備えることを特徴とするものである。各テーブルには伝搬路品質情報の値が対応する閾値とされる複数の送信モードが登録されており、複数のテーブルのいずれかが伝搬路環境情報に応じて選択され、該選択されたテーブルに登録されている送信モードのいずれかが伝搬路品質情報に応じて選択されるので、伝搬路環境情報および伝搬路品質情報に応じた送信モードが迅速に選択される。

従って、本発明によれば、伝搬路環境および伝搬路品質に応じた送信モードの選択を迅速に行うことができる効果がある。

また、送信モードを選択する際の伝搬路品質による閾値を誤り検出結果に応じて書き換える場合には、閾値の設定を伝搬路の状況に応じて最適なものとすることができるという効果が得られる。

上記ならびに他の多くの本発明の目的、態様、そして利点は、本発明の原理に合致する好適な具体例が実施例として示されている以下の記述および添付の図面に関連して説明されることにより、当該技術の熟達者にとって明らかになるであろう。

図面の簡単な説明

第１図は、従来の変調・符号化モード選択テーブルを説明するための図であり、

第２図は、従来の伝搬路状況に応じ閾値の可変制御を行う変調・符号化モード選択テーブルを説明するための図であり、

第３図および第４図は、本発明の第１の実施例による無線通信システムに用いられる、２つの無線装置の構成をそれぞれ示すブロック図であり、

第５図は、第１図に示される無線装置における変調・符号化モード選択部の詳細図であり、

第６図および第７図は、本発明の第２の実施例による無線通信システムに用いられる、２つの無線装置の構成をそれぞれ示すブロック図であり、そして

第８図は、第７図に示される無線装置における送信電力選択部の詳細図である。

発明を実施するための最良の形態

以下、本発明の幾つかの好ましい実施の形態が添付の図面を参照しながら詳細に説明される。

第３図および第４図は、本発明の第１の実施例による無線通信システムで用いられる、互いに無線通信を行ない合う無線装置１と無線装置２の構成をそれぞれ示すブロック図である。また、第５図は第３図中の変調・符号化モード選択部１６の構成を詳細に示すブロック図である。

第３図に示される無線装置１は、アンテナ１１と、送受信共用器１２（ＤＵＰ：duplexer）と、受信部１３と、信号分離部１４と、制御信号復調部１５と、変調・符号化モード選択部（送信モード選択部）１６と、変調・符号化部１７と、信号合成部１８と、送信部１９から構成されている。

受信部１３はアンテナ１１および送受信共用器１２を介して受信した無線装置２からの信号を信号分離部１４に送出する。信号分離部１４は無線装置２からの信号をデータ信号Ｓ１と制御信号Ｓ２とに分離して、制御信号Ｓ２を制御信号復調部１５に送出する。制御信号復調部１５は制御信号を復調して制御情報Ｓ３とし、該制御情報Ｓ３に含まれる伝搬路品質情報、伝搬路環境情報および誤り検出結果を変調・符号化モード選択部１６に送出する。

変調・符号化モード選択部１６は複数の変調・符号化モードからなる変調・符号化モード選択テーブルを複数備えるもので、各変調・符号化モード選択テーブルにおける複数の変調・符号化モードは異なる伝搬路品質の値（閾値）に対応して保存されている。

変調・符号化モード選択部１６は、制御信号復調部１５から送られてくる制御情報Ｓ３に含まれる伝搬路環境情報に基づいて複数の変調・符号化モード選択テーブルのいずれかを選択し、制御情報Ｓ３に含まれる伝搬路品質情報に基づいて

選択した変調・符号化モード選択テーブルの中から変調・符号化モードを選択し、その選択結果を変調・符号化モード情報として変調・符号化部１７に送出する。

第５図は、第１図に示される無線装置１における変調・符号化モード選択部１６の詳細図である。変調・符号化モード選択部１６は、選択制御部１６ａとテーブル切替えスイッチ１６ｂと、変調・符号化モード選択テーブル群１６ｃと、閾値可変制御部１６ｄから構成されている。

変調・符号化モード選択テーブル群１６ｃにはパス数Ｐ＝１，２，３，４、最大ドップラ周波数ｆd＝１０，１００，２００Ｈｚ（閾値５０Ｈｚ，１５０Ｈｚ）のそれぞれに対応した１２個の変調・符号化モード選択テーブル（Ｐ，ｆd）＝（１，１０），（１，１００），・・・，（４，１００），（４，２００）＝＃１～＃１２が登録されている。この変調・符号化モード選択テーブルはパス数Ｐと最大ドップラ周波数ｆｄの種類に応じた任意の数用意される。

選択制御部１６ａは、制御情報Ｓ３に含まれる伝搬路環境情報に基づいてテーブル切替えスイッチ１６ｂを制御し、変調・符号化モード選択テーブル群１６ｃの中から使用する変調・符号化モード選択テーブルを選択する。一例として推定したパス数が２、最大ドップラ周波数が８０Ｈｚの場合には、パス数２と、閾値５０Ｈｚ，１５０Ｈｚに基づいて最大ドップラ周波数１００Ｈｚに対応する変調・符号化モード選択テーブル＃５＝（２，１００）が選択される。また推定パス数が４より大きい場合にはパス数４に対応する変調・符号化モード選択テーブルが選択される。

次に、選択制御部１６ａは、制御情報Ｓ３に含まれる伝搬路品質情報を、テーブル群１６ｃの上記で選択された変調・符号化モード選択テーブルに保存されている複数の閾値と比較し、どの変調・符号化モードを選択するかを決定し、変調・符号化モード情報Ｓ４として出力する。

閾値可変制御部１６ｄは制御情報Ｓ３に含まれる誤り検出結果に基づいて、変

調・符号化モード選択テーブルに保存されている複数の閾値の書き換えを行う。情報ブロックの受信が成功した場合には、現在用いられている変調・符号化モードに対応する伝搬路品質の範囲の閾値レベルを所定の値ＰdownｄＢだけ下げ、情報ブロックの受信が所定回数だけ失敗した場合に閾値レベルを所定の値ＰupｄＢだけ上げる。

変調・符号化部１７は入力される情報ビットＳ５に対して変調・符号化モード情報Ｓ４に基づいた符号化を行い、変調を施す。その後ＣＲＣ（Cyclic Redundancy Check）符号を付加したデータ信号Ｓ６として信号合成部１８に送出する。信号合成部１８はデータ信号Ｓ６、パイロット信号Ｓ７および変調・符号化モード情報を示す制御信号Ｓ８を合成し、送信部１９と送受信共用器１２を介してアンテナ１１より無線装置２へ送出する。

第４図に示される無線装置２は、アンテナ２０１と、送受信共用器（ＤＵＰ）２０２と、受信部２０３と、信号分離部２０４と、制御信号復調部２０５と、データ信号復調・復号部２０６と、誤り検出部２０７と、伝搬路環境推定部２０８と、伝搬路品質推定部２０９と、信号合成部２１０と、送信部２１１から構成されている。

受信部２０３はアンテナ２０１および送受信共用器２０２を介して受信した無線装置１からの信号を信号分離部２０４に送出する。信号分離部２０４は無線装置１からの信号をデータ信号Ｓ２１と制御信号Ｓ２２とパイロット信号Ｓ２３を分離して、データ信号Ｓ２１をデータ信号復調・復号部２０６に送出し、制御信号Ｓ２２を制御信号復調部２０５に送出し、パイロット信号Ｓ２３を伝搬路環境推定部２０８および伝搬路品質推定部２０９に送出する。

制御信号復調部２０５は制御信号Ｓ２２を復調して制御情報とし、該制御情報に含まれる変調方式および符号化率を指定する変調・符号化モード情報Ｓ２４をデータ信号復調・復号部２０６に送出する。データ信号復調・復号部２０６は変

調・符号化モード情報２４で指定された変調方式および符号化率で信号分離部２０４から送られてきたデータ信号Ｓ２１の復調・復号を行い、復号データを誤り検出部２０７に送出する。

誤り検出部２０７ではデータ信号復調・復号部２０６で復号されたデータに付加されているＣＲＣ符号を用いて情報データブロックの受信誤りの有無を判定し、誤り検出結果Ｓ２５として信号合成部２１０に送出する。

伝搬路環境推定部２０８は入力されたパイロット信号Ｓ２３により伝搬路環境を推定し、これを伝搬路環境情報Ｓ２６として信号合成部２１０に送出する。伝搬路品質推定部２０９では入力されたパイロット信号Ｓ２３により信号電力対干渉比（ＳＩＲ）及び信号対雑音（S／N）比を推定し、これを伝搬路品質情報として信号合成部２１０に送出する。

信号合成部２１０では送信用のデータ信号Ｓ２８と誤り検出結果Ｓ２５と伝搬路環境情報Ｓ２６と伝搬路品質情報Ｓ２７とが合成され、送信部２１１と送受信共用器２０２を介してアンテナ２０１より無線装置１へ送出される。無線装置１側ではデータ信号Ｓ２８はデータ信号Ｓ１とされ、誤り検出結果Ｓ２５と伝搬路環境情報Ｓ２６と伝搬路品質情報Ｓ２７は制御情報Ｓ３として使用される。

以上の動作により、伝搬路状況に応じた変調・符号化モード選択テーブルの最適な設定を迅速かつ容易に行うことができる。

次に、本発明の第２の実施例について説明する。無線通信システムにおいて高品質なデータ伝送方法を実現する別の方法として、伝搬路品質が一定となるように送信電力を適応制御する方法がある。この実現方法としては目標の通信品質（ブロック誤り率、ビット誤り率、スループット量などで示される）を満足させることができる伝搬路品質を各々の変調・符号化モードで目標伝搬路品質として予め設定しておく。

受信装置では伝搬路品質を推定し、現在使用している変調・符号化モードの目

標伝搬路品質と推定伝搬路品質を比較する。推定伝搬路品質が目標伝搬路品質より小さい場合には送信電力を上げるように送信側へ指示し、推定伝搬路品質が目標伝搬路品質より小さい場合には送信電力を下げるように送信側へ指示する。

しかしながら、伝搬路環境が異なれば目標の通信品質を満足させることができる最適な目標伝搬路品質は変化する。ここでの最適な目標伝搬路品質とは、目標の通信品質を満足させることができる最小の伝搬路品質値である。このような場合にも上記変調・符号化モードの閾値設定時と同様に、各々の変調・符号化モードに対応する伝搬路品質の目標値の最適な設定が難しいという問題がある。本発明の構成は上記問題に対しても適応可能である。このような実施例を本発明の第２の実施例として以下に説明する。

第６図および第７図は、本発明の第２の実施例による無線通信システムに用いられる、互いに無線通信を行ない合う無線装置４と無線装置５の構成をそれぞれ示すブロック図である。

第６図に示される無線装置４は、アンテナ４１と、送受信共用器４２（ＤＵＰ）と、受信部４３と、信号分離部４４と、制御信号復調部４５と、送信電力制御部４６と、送信部４７を含んで構成されている。

受信部４３はアンテナ４１および送受信共用器４２を介して受信した無線装置５からの信号を信号分離部４４に送出する。信号分離部４４は受信部４３から受信した信号をデータ信号Ｓ４１と制御信号Ｓ４２に分離して、制御信号Ｓ４２を制御信号復調部４５に送出する。制御信号復調部４５は制御信号Ｓ４２を復調して制御情報とし、該制御情報に含まれる送信電力制御モード情報Ｓ４３を送信電力制御部４６に送出する。

送信電力制御部４６は入力された送信電力制御モード情報Ｓ４３に基づいて送信電力設定値Ｓ４４を決定し、送信部４７に送出する。送信部４７は送信電力制御部４６からの送信電力設定値Ｓ４４に応じて送信信号Ｓ４５を増幅する。送信

信号Ｓ４５は、変調・符号化モードを示す制御信号と、該変調・符号化モードによるデータ信号と、パイロット信号とが合成されたもので、増幅された送信信号は送受信共用器４２を介してアンテナ４１より無線装置５へ送出される。

無線装置５は、アンテナ５０１と、送受信共用器５０２と、受信部５０３と、信号分離部５０４と、制御信号復調部５０５と、伝搬路環境推定部５０６と、伝搬路品質推定部５０７と、送信電力選択部（送信モード選択部）５０８と、信号合成部５０９と、送信部５１０とを含んで構成されている。

受信部５０３は、アンテナ５０１および送受信共用器（DUP）５０２を介して受信した無線装置４からの信号を信号分離部５０４に送出する。信号分離部５０４は受信部５０３から受信した信号をデータ信号Ｓ５１と制御信号Ｓ５２とパイロット信号Ｓ５３に分離して、制御信号Ｓ５２を制御信号復調部５０５に送出し、パイロット信号Ｓ５３を伝搬路環境推定部５０６と伝搬路品質推定部５０７に送出する。

制御信号復調部５０５は制御信号Ｓ５２を復調して制御情報とし、該制御情報に含まれる変調・符号化モード情報Ｓ５４を送信電力選択部５０８に送出する。伝搬路環境推定部５０６はパイロット信号Ｓ５３を入力として伝搬路環境を推定し、これを伝搬路環境情報Ｓ５５として送信電力選択部５０８に送出する。伝搬路品質推定部５０７はパイロット信号を入力として信号電力対干渉比（ＳＩＲ）及び信号対雑音比（S／N）を推定し、これを伝搬路品質情報Ｓ５６として送信電力選択部５０８に送出する。

第８図は、第７図に示される無線装置５における送信電力選択部５０８の詳細図である。送信電力選択部５０８は選択制御部５０８ａとテーブル切替えスイッチ５０８ｂと送信電力制御モード選択テーブル群５０８ｃから構成されている。

送信電力制御モード選択テーブル群５０８ｃにはパス数１，４，８，１２（閾値２，６，９,）、遅延分散１０，４０，１００ｎｓ（閾値２０ｎｓ，７０ｎｓ）

の組み合わせに対応させた１０個の送信電力制御モードテーブル（P，σ）＝（1，x），（4，１０），（4，４０），・・・（１２，４０），（１２，１００）＝＃１～＃１０が登録されている。ただし、ｘは値を割り当てないことを表している。送信電力制御モードテーブルはパス数および遅延分散の種類に応じた任意の数用意される。

各送信電力制御モード選択テーブルには複数の変調・符号化モードに対してそれぞれ異なる値の目標伝搬路品質値が保存されている。送信電力選択部５０８は伝搬路品質推定部５０７からの伝搬路品質情報Ｓ５５を受け付けると、伝搬路環境情報Ｓ５５に基づいてテーブル切替えスイッチ５０８ｂを制御し、送信電力制御モードテーブル群５０８ｃの中から使用するテーブルを選択する。一例として推定したパス数が７、遅延分散が１１０ｎｓであった場合、閾値6，９に基づいてパス数８、閾値７０に基づいて遅延分散１００ｎｓに対応するテーブル＃７＝（8，１００）が選択される。

次に、伝搬路品質情報Ｓ５６に示される推定伝搬路品質値を、選択したテーブルに保存された現在使用している変調・符号化モードに対応して設定されている目標伝搬路品質値と比較する。推定伝搬路品質値が目標伝搬路品質値より小さい場合には送信電力を上げることを決定し、推定伝搬路品質が目標伝搬路品質より大きい場合には送信電力を下げることを決定し、決定した内容を送信電力制御モード情報Ｓ５７として信号合成部５０９に送出する。

信号合成部５０９ではデータ信号Ｓ５８と送信電力制御モード情報Ｓ５７を合成し、これを送信部５１０と送受信共用器５０２を介してアンテナ５０１より無線装置４へ送出する。

以上の動作により、伝搬路の状況に応じた送信電力の最適な設定を迅速かつ容易に行うことができる。

請 求 の 範 囲

１．　互いに無線通信を行なう第一無線装置と第二無線装置とを有する無線通信システムであって、

前記第一無線装置は、

前記第二無線装置からの信号から前記第二無線装置との伝搬路の環境を推定した結果を伝搬路環境情報として出力する伝搬路環境推定部と、

前記第二無線装置からの信号から前記第二無線装置との伝搬路の品質を推定した結果を伝搬路品質情報として出力する伝搬路品質推定部と、

前記伝搬路環境情報および伝搬路品質情報をデータ信号とともに前記第二無線装置に送信する送信手段とを具備し、

前記第二無線装置は、

前記伝搬路品質情報の値が対応する閾値とされる複数の送信モードが登録されている複数のテーブルを備え、複数のテーブルのいずれかを前記伝搬路環境情報に応じて選択し、該選択したテーブルに登録されている前記送信モードのいずれかを前記伝搬路品質情報に応じて選択して前記第一無線装置への送信モードとする送信モード選択部を具備する

ことを特徴とする無線通信システム。

２．　請求項１記載の無線通信システムにおいて、

第一無線装置は、

第二無線装置からの信号における誤りを検出して誤り検出結果として出力する誤り検出部を備え、

送信手段は、伝搬路環境情報、伝搬路品質情報、そして前記誤り検出結果をデータ信号とともに前記第二無線装置に送信し、

前記第二無線装置の送信モード選択部は、前記誤り検出結果に応じて選択した

送信モードに対応してテーブルに登録されている閾値を書き換えることを特徴とする無線通信システム。

3．　請求項１または請求項２記載の無線通信システムにおいて、伝搬環境情報としてパス数を用いることを特徴とする無線通信システム。

4．　請求項３記載の無線通信システムにおいて、複数のテーブルがパス数P1, P2, …, PR（P1, P2, …, PRは自然数で、P1＜P2＜…＜PRを満たす）に対応することを特徴とする無線通信システム。

5．　請求項１または請求項２に記載の無線通信システムにおいて、伝搬路環境情報として最大ドップラ周波数を用いることを特徴とする無線通信システム。

6．　請求項５記載の無線通信システムにおいて、複数のテーブルが最大ドップラ周波数ｆ0, ｆ1, …, ｆR-1（ｆ0＜ｆ1＜…＜ｆR-1）に対応し、閾値ｘｉ（ｘｉはｆｉ＜ｘｉ＜ｆｉ+1 を満たす任意の数、ｉは０以上Ｒ－２以下の整数）に対し、最大ドップラ周波数ｆｄがｘｊ-1＜ｆｄ≦ｘｊ（ｊは１以上、Ｒ－２以下の整数）のとき最大ドップラ周波数としてｆｊ、ｆｄ≦ｘ0 のとき最大ドップラ周波数としてｆ0、ｆｄ＞ｘR-2 のとき最大ドップラ周波数としてｆR-1 を選択することを特徴とする無線通信システム。

7．　請求項１または請求項２に記載の無線通信システムにおいて、伝搬路環境情報として遅延分散を用いることを特徴とする無線通信システム。

8．　請求項７記載の無線通信システムにおいて、複数のテーブルが遅延分散σ0, σP, …, σq-1（σ0＜σ1＜…＜σR-1）に対応し、閾値ｘｉ（ｘｉはσｉ＜ｘｉ＜σｉ+1 を満たす任意の数、ｉは０以上Ｒ－２以下の整数）に対し、遅延分散σがｘｊ-1＜σ≦ｘｊ（ｊは１以上Ｒ－２以下の整数）のとき遅延分散としてσｊ, σ≦ｘ0 のとき遅延分散としてσ0、σ＞ｘR-2 のとき遅延分散としてσR-1 を選択することを特徴とする無線通信システム。

9．　請求項１または請求項２に記載の無線通信システムにおいて、複数の選択

テーブルがパス数P1，P2，…，PJ（P1，P2，…，PJはR以下の自然数でP1＜P2＜…＜PJ を満たす)、最大ドップラ周波数 f 0，f 1，… f K-1（KはR以下の自然数でJ×K＝Rを満たす）の組み合わせに対応することを特徴とする無線通信システム。

１０． 請求項１または請求項２に記載の無線通信システムにおいて、複数のテーブルがパス数P1，P2，…，PJ（P1，P2，…，PJは自然数でP1＜P2＜…＜PJ を満たす)、遅延分散σ0，σP，…，σk-1（LはR以下の自然数でJ×L＝R）の組み合わせ（ただしパス数が１のとき、前記遅延分散を前記伝搬路環境情報として使用しない）に対応することを特徴とする無線通信システム。

１１． 請求項１または請求項２に記載の無線通信システムにおいて、複数のテーブルが最大ドップラ周波数 f 0～ f K-1、遅延分散σ0～σL-1（LはR以下の自然数でK×L＝R）の組み合わせに対応することを特徴とする無線通信システム。

１２． 請求項１または請求項２に記載の無線通信システムにおいて、複数のテーブルがパス数P1，P2，…，PJ、最大ドップラ周波数 f 0～ f K-1、及び遅延分散σ0～σL-1（J，K，L，RはJ×K×L＝Rを満たす自然数）の組み合わせ（ただしパス数が１のとき、遅延分散を前記伝搬路環境情報として使用しない）に対応することを特徴とする無線通信システム。

１３． 請求項１または請求項２に記載の無線通信システムにおいて、伝搬路品質情報として信号対干渉比を用いることを特徴とする無線通信システム。

１４． 請求項１または請求項２に記載の無線通信システムにおいて、伝搬路品質情報として信号対雑音比を用いることを特徴とする無線通信システム。

１５． 請求項２に記載の無線通信システムにおいて、送信モードのパラメータとして変調方式を用いることを特徴とする無線通信システム。

１６． 請求項２に記載の無線通信システムにおいて、送信モードのパラメータとして符号化率を用いることを特徴とする無線通信システム。

１７．　請求項１に記載の無線通信システムにおいて、送信モードのパラメータとして送信電力を用いることを特徴とする無線通信システム。

１８．　互いに無線通信を行なう第一無線装置と第二無線装置とを有する無線通信システムで行なわれる送信モード選択方法であって、

前記第二無線装置からの信号から前記第二無線装置との伝搬路の環境を示す伝搬路環境情報を推定する、前記第一無線装置が行なう、第１のステップと、

前記第二無線装置からの信号から前記第二無線装置との伝搬路の品質を示す伝搬路品質情報を推定する、前記第一無線装置が行なう、第２のステップと、

前記伝搬路環境情報および伝搬路品質情報をデータ信号とともに前記第二無線装置に送信する、前記第一無線装置が行なう、第３のステップと、

前記伝搬路品質情報の値が対応する閾値とされる複数の送信モードが登録されている複数のテーブルのいずれかを前記伝搬路環境情報に応じて選択し、該選択したテーブルに登録されている前記送信モードのいずれかを前記伝搬路品質情報に応じて選択して前記第一無線装置への送信モードとする、前記第二無線装置が行なう、第４のステップと

を含むことを特徴とする送信モード選択方法。

１９．　互いに無線通信を行なう第一無線装置と第二無線装置とを有する無線通信システムで行なわれる送信モード選択方法であって、

前記第二無線装置からの信号から前記第二無線装置との伝搬路の環境を示す伝搬路環境情報を推定する、前記第一無線装置が行なう、第１のステップと、

前記第二無線装置からの信号から前記第二無線装置との伝搬路の品質を示す伝搬路品質情報を推定する、前記第一無線装置が行なう、第２のステップと、

前記第二無線装置からの信号における誤りを示す誤り検出結果を求める、前記第一無線装置が行なう、第３のステップと、

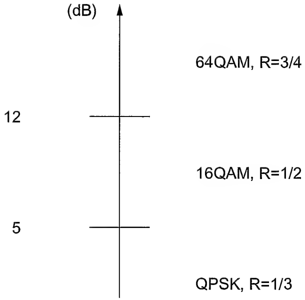
前記伝搬路環境情報、伝搬路品質情報および誤り検出結果をデータ信号とととも

に前記第二無線装置に送信する、前記第一無線装置が行なう、第４のステップと、

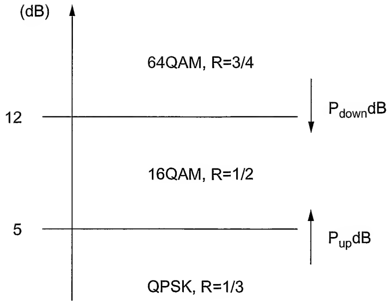
前記伝搬路品質情報の値が対応する閾値とされる複数の送信モードが登録されている複数のテーブルのいずれかを前記伝搬路環境情報に応じて選択し、該選択したテーブルに登録されている前記送信モードのいずれかを前記伝搬路品質情報に応じて選択して前記第一無線装置への送信モードとし、前記誤り検出結果に応じて選択した送信モードに対応してテーブルに登録されている閾値を書き換える、前記第二無線装置が行なう、第５のステップと

を含むことを特徴とする送信モード選択方法。

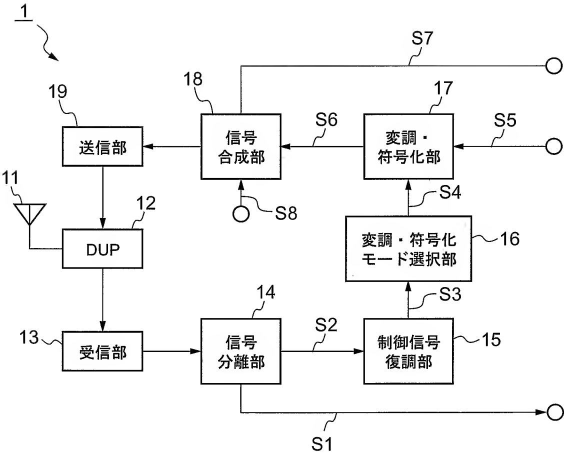
第1図


(dB)
64QAM, R=3/4
12
16QAM, R=1/2
5
QPSK, R=1/3

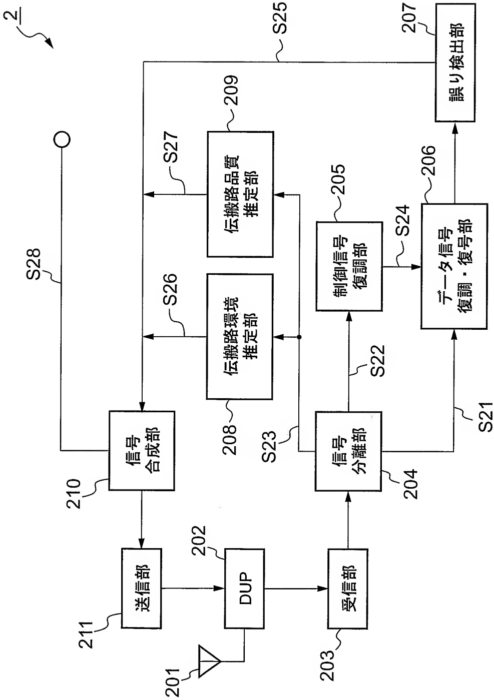
第2図


(dB)
64QAM, R=3/4
P_{down}dB
12
16QAM, R=1/2
5
P_{up}dB
QPSK, R=1/3

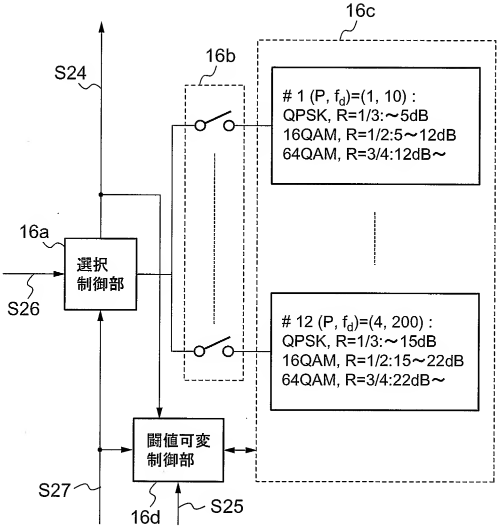
第3図


1
S7
18
17
19
S6
S5
送信部
信号
合成部
変調・
符号化部
11
S4
12
S8
DUP
変調・符号化
モード選択部
16
14
S3
13
S2
15
受信部
信号
分離部
制御信号
復調部
S1

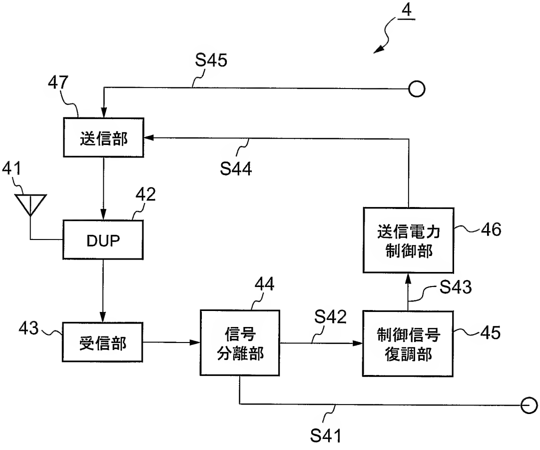
第4図


2
201
DUP
202
送信部
211
受信部
203
信号合成部
210
信号分離部
204
伝搬路環境推定部
208
伝搬路品質推定部
209
制御信号復調部
205
データ信号復調・復号部
206
誤り検出部
207
S21
S22
S23
S24
S25
S26
S27
S28

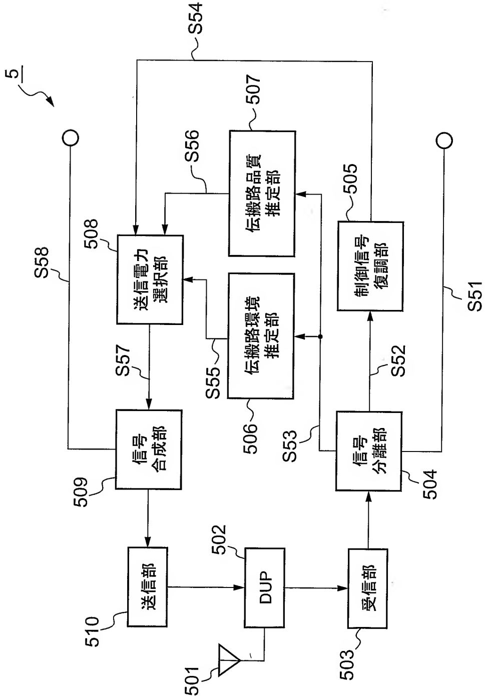
第5図


16c
16b
S24
1 (P, f_d)=(1, 10) :
QPSK, R=1/3:～5dB
16QAM, R=1/2:5～12dB
64QAM, R=3/4:12dB～
16a
選択
制御部
S26
12 (P, f_d)=(4, 200) :
QPSK, R=1/3:～15dB
16QAM, R=1/2:15～22dB
64QAM, R=3/4:22dB～
闘値可変
制御部
S27
16d
S25

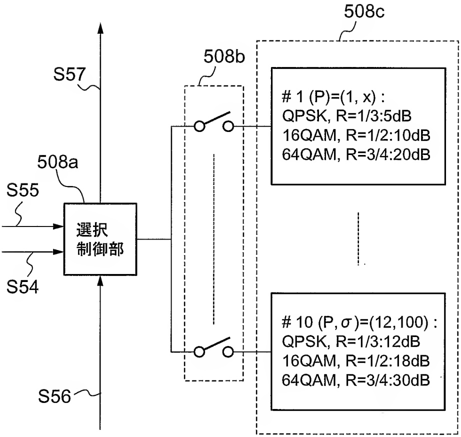
第6図


4
S45
47
送信部
S44
41
42
DUP
送信電力
制御部
46
S43
44
43
受信部
信号
分離部
S42
制御信号
復調部
45
S41

第7図


5
伝搬路品質推定部
伝搬路環境推定部
送信電力選択部
制御信号復調部
信号合成部
信号分離部
送信部
DUP
受信部
501
502
503
504
505
506
507
508
509
510
S51
S52
S53
S54
S55
S56
S57
S58

第8図


508c
508b
S57
1 (P)=(1, x) :
QPSK, R=1/3:5dB
16QAM, R=1/2:10dB
64QAM, R=3/4:20dB
508a
S55
選択
制御部
S54
10 (P, σ)=(12,100) :
QPSK, R=1/3:12dB
16QAM, R=1/2:18dB
64QAM, R=3/4:30dB
S56

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2004/009463

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl^7 H04Q7/22, H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl^7 H04B7/24-7/26, H04Q7/00-7/38, H04L1/00, H04L13/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Toroku Jitsuyo Shinan Koho	1994-2004
Kokai Jitsuyo Shinan Koho	1971-2004	Jitsuyo Shinan Toroku Koho	1996-2004

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2002-44168 A (Matsushita Electric Industrial Co., Ltd.), 08 February, 2002 (08.02.02), Page 5, right column, line 41 to page 7, left column, line 6; Fig. 5 & WO 2002/09377 A1 & EP 1213888 A1 & US 6788737 B1 & AU 2001/72766 A & CN 1386351 A & KR 2002/032620 A	1-19

[X] Further documents are listed in the continuation of Box C.   [ ] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 September, 2004 (28.09.04)	12 October, 2004 (12.10.04)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2002-271294 A (Matsushita Electric Industrial Co., Ltd.), 20 September, 2002 (20.09.02), Page 2, right column, line 29 to page 4, left column, line 14; page 5, right column, line 43 to page 6, right column, line 34; Figs. 3, 20 (Family: none)	1-19
Y	JP 2003-37554 A (NEC Corp.), 07 February, 2003 (07.02.03), Full text; Figs. 1 to 22 & EP 1259015 A2 & US 2002/173312 A1 & CN 1387328 A & KR 2002/089152 A	1-19
Y	JP 2002-101043 A (Matsushita Electric Industrial Co., Ltd.), 05 April, 2002 (05.04.02), Page 7, left column, line 31 to page 10, right column, line 2; Fig. 3 & WO 2002/01760 A1 & EP 1204225 A1 & US 2992/123349 A1 & AU 2001/74606 A & CN 1386337 A & KR 2002/026601 A	1-19
Y	JP 08-181653 A (NTT Mobile Communications Network Inc.), 12 July, 1996 (12.07.96), Full text; Figs. 1 to 20 & EP 709973 A1 & US 5873028 A & CN 1123976 A	3,4,9,10,12, 17
A	JP 2003-143071 A (Matsushita Electric Industrial Co., Ltd.), 16 May, 2003 (16.05.03), Full text; Figs. 1 to 13 (Family: none)	1-19
A	JP 2001-196974 A (NTT Docomo Inc.), 19 July, 2001 (19.07.01), Full text; Figs. 1 to 9 (Family: none)	1-19

Ａ．　発明の属する分野の分類（国際特許分類（ＩＰＣ））
Ｉｎｔ．Ｃｌ^{7}　Ｈ０４Ｑ７／２２，　Ｈ０４Ｑ７／３８

Ｂ．　調査を行った分野
調査を行った最小限資料（国際特許分類（ＩＰＣ））
Ｉｎｔ．Ｃｌ^{7}　Ｈ０４Ｂ７／２４－７／２６，　Ｈ０４Ｑ７／００－７／３８
Ｈ０４Ｌ１／００，　Ｈ０４Ｌ１３／００

最小限資料以外の資料で調査を行った分野に含まれるもの

日本国実用新案公報	１９２２－１９９６年
日本国公開実用新案公報	１９７１－２００４年
日本国登録実用新案公報	１９９４－２００４年
日本国実用新案登録公報	１９９６－２００４年

国際調査で使用した電子データベース（データベースの名称、調査に使用した用語）

Ｃ．　関連すると認められる文献

引用文献の カテゴリー＊	引用文献名　及び一部の箇所が関連するときは、その関連する箇所の表示	関連する 請求の範囲の番号
Ｙ	ＪＰ　２００２－４４１６８　Ａ（松下電器産業株式会社） 第５頁右欄第４１行－第７頁左欄第６行，第５図 ２００２．０２．０８ ＆　ＷＯ　２００２／０９３７７　Ａ１ ＆　ＥＰ　１２１３８８８　Ａ１ ＆　ＵＳ　６７８８７３７　Ｂ１ ＆　ＡＵ　２００１／７２７６６　Ａ ＆　ＣＮ　１３８６３５１　Ａ ＆　ＫＲ　２００２／０３２６２０　Ａ	1-19

☒　Ｃ欄の続きにも文献が列挙されている。　　☐　パテントファミリーに関する別紙を参照。

＊　引用文献のカテゴリー
「Ａ」特に関連のある文献ではなく、一般的技術水準を示すもの
「Ｅ」国際出願日前の出願または特許であるが、国際出願日以後に公表されたもの
「Ｌ」優先権主張に疑義を提起する文献又は他の文献の発行日若しくは他の特別な理由を確立するために引用する文献（理由を付す）
「Ｏ」口頭による開示、使用、展示等に言及する文献
「Ｐ」国際出願日前で、かつ優先権の主張の基礎となる出願の日の後に公表された文献
「Ｔ」国際出願日又は優先日後に公表された文献であって出願と矛盾するものではなく、発明の原理又は理論の理解のために引用するもの
「Ｘ」特に関連のある文献であって、当該文献のみで発明の新規性又は進歩性がないと考えられるもの
「Ｙ」特に関連のある文献であって、当該文献と他の１以上の文献との、当業者にとって自明である組合せによって進歩性がないと考えられるもの
「＆」同一パテントファミリー文献

国際調査を完了した日 ２８．０９．２００４	国際調査報告の発送日 12.10.2004
国際調査機関の名称及びあて先 日本国特許庁（ＩＳＡ／ＪＰ） 郵便番号１００－８９１５ 東京都千代田区霞が関三丁目４番３号	特許庁審査官（権限のある職員）　５Ｊ　３２４９ 桑江　晃 電話番号　０３－３５８１－１１０１　内線　３５３４

Ｃ（続き）．　関連すると認められる文献

引用文献のカテゴリー＊	引用文献名　及び一部の箇所が関連するときは、その関連する箇所の表示	関連する請求の範囲の番号
Ｙ	ＪＰ　２００２－２７１２９４　Ａ（松下電器産業株式会社） 第２頁右欄第２９行－第４頁左欄第１４行, 第５頁右欄第４３行－第６頁右欄第３４行，第３，２０図 ２００２．０９．２０ （ファミリーなし）	1-19
Ｙ	ＪＰ　２００３－３７５５４　Ａ（日本電気株式会社） 全文，第１－２２図　２００３．０２．０７ ＆　ＥＰ　１２５９０１５　Ａ２ ＆　ＵＳ　２００２／１７３３１２　Ａ１ ＆　ＣＮ　１３８７３２８　Ａ ＆　ＫＲ　２００２／０８９１５２　Ａ	1-19
Ｙ	ＪＰ　２００２－１０１０４３　Ａ（松下電器産業株式会社） 第７頁左欄第３１行－第１０頁右欄第２行，第３図 ２００２．０４．０５ ＆　ＷＯ　２００２／０１７６０　Ａ１ ＆　ＥＰ　１２０４２２５　Ａ１ ＆　ＵＳ　２９９２／１２３３４９　Ａ１ ＆　ＡＵ　２００１／７４６０６　Ａ ＆　ＣＮ　１３８６３３７　Ａ ＆　ＫＲ　２００２／０２６６０１　Ａ	1-19
Ｙ	ＪＰ　０８－１８１６５３　Ａ（エヌ・ティ・ティ移動通信網株式会社）　全文，第１－２０図　１９９６．０７．１２ ＆　ＥＰ　７０９９７３　Ａ１　＆　ＵＳ　５８７３０２８　Ａ ＆　ＣＮ　１１２３９７６　Ａ	3, 4, 9, 10, 12, 17
Ａ	ＪＰ　２００３－１４３０７１　Ａ（松下電器産業株式会社） 全文，第１－１３図　２００３．０５．１６ （ファミリーなし）	1-19
Ａ	ＪＰ　２００１－１９６９７４　Ａ（株式会社エヌ・ティ・ティ・ドコモ）　全文，第１－９図　２００１．０７．１９ （ファミリーなし）	1-19